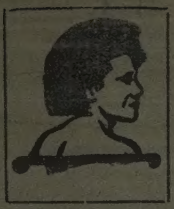
VOL. 21 NOS. 1 - 2 MARCH - JUNE, 1950



COLONY OF FIJI

AGRICULTURAL JOURNAL

ISSUED BY THE

DEPARTMENT OF AGRICULTURE, FIJI

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Notes for Libraries and Research Institutes.

FORMER ISSUES OF AGRICULTURAL JOURNAL.

So many requests are received from abroad for parts of the *Agricultural Journal* which were never published that the following list of all issues published and those which are not now available is given for reference. Attention is especially directed to Volume 7 which had only one part:—

Vol.				*Vol.*			
1.	3	numbers,	1928.	11.	4	numbers,	1940 (none).
2.	4	„	1929.	12.	4	„	1941 (none of Nos. 1 and 2).
3.	3	„	1930 (none).				
4.	4	„	1931.	13.	4	„	1942.
5.	2	„	1932 (none of No. 2).	14.	4	„	1943.
6.	2	„	1933.	15.	4	„	1944.
7.	1	„	1934.	16.	4	„	1945.
8.	4	„	1935–37 (none of No. 4).	17.	4	„	1946 (none of No. 1).
9.	4	„	1938 (none of Nos. 2, 3 and 4).	18.	4	„	1947 (none of No. 1).
				19.	4	„	1948 (Nos. 3 & 4 form a double issue.)
10.	4	„	1939 (none of Nos. 2 and 4).	20.	4	„	1949.

ISSUES OF THE AGRICULTURAL CIRCULAR.

NUMBERS and year of issue of the *Agricultural Circular* :—

Vol. 1, 1920, 12 numbers.
2, 1921, 5 „
3, 1922, 4 „
Vol. 4, 1923, 1 number.
5, 1924–5, 2 numbers.

As number 4 of Vol. 3 was printed as " Volume 4 " and number 1 of Vol. 4 as " Volume 5 " it would appear from an inspection of a complete set that Volume 4 comprised only a number 4 and that there were two issues of Volume 5, No. 1.

ANNUAL BULLETINS.

THE Annual Bulletin of Divisional Reports ran from 1931 to 1938 and was then discontinued.

OLD ISSUES OF AGRICULTURAL BULLETINS.

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9. Soils of Fiji—I, 1916.
11. Alluvial Soils of Fiji, 1919.
12. Leaf Moth of Coconuts, 1919.
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14. Transparent Coconut Scale, 1921.
15. Purple Leaf Moth of Coconuts, 1924.
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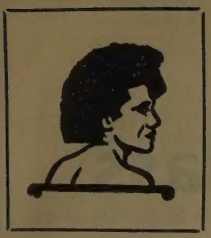
Applications should be made to the Librarian, Department of Agriculture, Suva, Fiji.

—EDITOR.



Agricultural Journal

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EDITORIAL . . .

FIELD DAY—SIGATOKA AGRICULTURAL STATION

A Field Day was held at the Agricultural Station, Sigatoka, on September 7th and was attended by a large number of guests, amongst whom were His Excellency the Governor, Sir Brian Freeston, K.C.M.G., O.B.E., and Lady Freeston, interested citizens and farmers from all the principal agricultural districts of Viti Levu.

The visitors were welcomed by the Acting Director of Agriculture, Mr. W. J. Blackie, who outlined for them the general aims of the Department's experimental policy. Dr. W. J. A. Payne, Animal Husbandry Officer, who is in charge of the Station, explained the layout of the farm and described the work in progress.

While the emphasis at Sigatoka is laid on livestock production, cropping work is also carried out under a ley-farming system. The importance of pasture research is closely bound up with that of animal production and an interesting address was given by Mr. W. I. Laing, a member of the Station staff, on the investigational work being carried out in pasture and fodder crop research. Grasses and legumes from all over the Colony, as well as from overseas, are being assembled (there are now upwards of seventy species and varieties of pasture plants at Sigatoka) and their yield and management carefully studied. While it is unfortunately true that the productivity of many Fiji pastures is low, this is felt to be due to management rather than to initial composition, and stress was laid on the necessity for heavy stocking under a controlled system of rotational grazing in order to keep down weeds and let in sufficient light to give a chance to the legumes (especially low-growing ones) which are essential from both the fertility and and nutrition points of view. Three of our main grasses, viz.: Guinea, Para and Nawai or Nadi Bluegrass[1] are considered to be both palatable and highly productive, while amongst legumes *Calopogonium* and *Centrosema* flourish in the Sigatoka area, and Creeping Indigo[2], a recent importation, is showing promise and may become useful for both low and high growing pastures. The desirability of converting into silage surplus pasture growth during the wet season against not a rainy but a dry day or spell was also emphasized.

In the afternoon Dr. Payne gave an address on animal production in Fiji, and this was followed by livestock demonstrations. It was pointed out by Dr. Payne that present needs call for a diversification of farming and for self-sufficiency in food crops, especially for the production of protein and protective foods—milk, eggs, butter, ghee and meat—hence the supreme importance of animal production. There are three major problems confronting the animal husbandry expert: (1) the selection of type and breed of animal; (2) the selection of the highly productive animal within group (1), from which the herds will be built up with a view to the distribution later on of good stock throughout the Colony; and (3) the management and feeding systems likely to achieve the best results in health and production. The day of the triple-purpose animal is almost over, and even in the Zebu breed a single or dual-purpose animal is now being evolved overseas, although we have no milch types of Zebu in Fiji. There are also three possible methods of attack on these problems: (1) to import European cattle and select for heat tolerance; (2) to import Zebus and select for milk production, or (3) to cross European and Zebu cattle and hope in so doing to stabilize both characteristics in a new breed. A new approach to selection is proposed at Sigatoka, namely selection for heat tolerance of highly productive animals of European breed.

Especial interest was shown by the visitors in the Fiji end of the twin calf investigations, eight of the Jersey heifer

identical twins having arrived at Sigatoka on April 24th. Comparisons between them and the remaining eight at Ruakura Animal Research Institute in New Zealand, fed and managed identically, will narrow down to purely climatic causes any discrepancies in growth and eventual production, and should furnish a most valuable pointer to sound livestock development in the Colony, and elsewhere in the tropics.

Work is therefore being carried out with Friesians, Illawarra Shorthorns and Zebu cattle in the Station herd and with Jerseys amongst the experimental animals. Selection work is at present restricted to dairy cattle, but will soon extend to include pigs and goats; records are already being kept of animals in the pig and goat herds. In order to increase rapidly the progeny of the animals finally selected for breeding purposes among the dairy cattle it may be possible to utilize the new physiological technique of artificial pregnancy.

Interesting work has also been done in the field of animal behaviour, which has brought to light the important fact that European-type dairy cattle in Fiji graze mainly at night and that therefore any system of management which deprives them of access to pasture at night will have a deleterious effect on their intake of food and consequently on their production. The information resulting from this investigation has been so valuable that it is intended to investigate the behaviour of other breeds of cattle, including Zebu, and later on goats so that the management of these animals also may be placed on a scientific basis.

Further Field Days will be held at Sigatoka next year when the work now being done may be expected to have yielded results which will be passed on to the farming community of the Colony.

—M.C.D.

[1] *Dicanthium caricosum*
[2] *Indigofera endecaphylla*

STAFF NOTES

Mr. C. Harvey, Director of Agriculture, proceeded on overseas leave on 9th April, 1950.

Mr. W. J. Blackie, Deputy Director of Agriculture, was appointed to act as Director from 9th April, 1950.

Mr. B. E. V. Parham, Senior Agricultural Officer, returned from overseas leave and resumed duty, as Acting Deputy Director of Agriculture, with effect from 3rd June, 1950.

Mr. L. W. Harwood, Agricultural Officer South, was appointed to act as Senior Agricultural Officer in his place, with effect from 21st June, the date on which Mr. M. D. ffrench-Mullen, who had been acting Senior Agricultural Officer, left the Colony on transfer to British Guiana.

Mr. A. F. S. Ohman, was appointed Senior Veterinary Officer with effect from 1st January, and assumed duty on 17th January, 1950.

Mr. N. G. Cassidy, was appointed Senior Chemist with effect from 26th January and assumed duty on 4th February, 1950.

Mr. H. J. Hulek, Office Superintendent, was transferred to the Department of Education with effect from the 5th April, his place being filled by Mr. J. S. Rennie on transfer from the Lands Department.

Mr. T. P. Gardiner, Senior Livestock Officer, returned from overseas leave and resumed duty on 28th April, 1950.

Mr. C. E. Whitehead was confirmed in his appointment as Soil Conservation Officer.

Miss M. V. Branster, Junior Laboratory Assistant, resigned from her post on 25th June in order to visit the United States.

Members of the staff met together on 20 JUN 1950 at a farewell party given in honour of Mr. M. D. ffrench-Mullen on the eve of his departure to take up the post of Chief Scientific Officer in British Guiana. Mr. ffrench-Mullen came to Fiji in 1940 and leaves behind him a reputation for able and energetic service.

AGRICULTURE

OBSERVATIONS ON INDIGENOUS SYSTEMS OF AGRICULTURE

BY L. W. HARWOOD, H.D.A.

This article has been prompted by the subject matter of a recent publication—" Soil Conservation—An International Study." The authors claim that polycultural agricultural practices, in the tropics, are, in the main, preferable to monocultural systems, and although such an assertion cannot be wholly supported by scientific facts, it does appear that the traditional methods of the indigenous people in such regions are worthy of investigation. In view of the authors' claims which are summarised in the paragraph quoted hereunder, a study of traditional agricultural practices in Fiji and other tropical countries may be of interest.

" The apparently haphazard intersowing of early and late maturing grains and of legumes, with cereals and root crops, which is practised by many primitive tribes, is now recognised as a highly developed and efficacious technique, which stands up to the vagaries of climate and to insect pests and which probably allows the cereals to benefit from the proximity of legume roots. Elaborate and careful experiments extending over several years, are required before greatly changing these practices."

Virgin tropical soils, especially those developed under shade, produce satisfactory crops, for a short period of years, without the addition of artificial fertilizers. Soils of this type possess great stores of natural fertility, and the system of shifting cultivation, peculiar to the tropics, appears to have been designed by peoples conscious of this fact. The agricultural practices in such regions varied according to the rainfall and the customs of the people. In the drier lands, where the wet season was of short duration, the country was usually under grass, which supported herds of cattle owned by nomadic tribes. A system of shifting cultivation was the universal rule in regions where the rainy weather lasted from four to six months, whilst the country was covered with forest when the wet season exceeded that period.

Shifting cultivation may be described as a form of agriculture, designed to utilize the natural fertility of the soil and at the same time require the minimum of effort by the operator. Systems varied from country to country, but the essential features were the same. The forest, or trees below a certain girth, having been felled, and burned, combinations of crops were planted on the land. The cropping continued until one to three cycles had been completed, when the land reverted to jungle. It would be again cleared for cultivation after eight to fifty years, depending on the density of the population and the forest growth. When adequate land and time to effect regeneration are available, shifting cultivation, as practised by the Fijians and other peoples, is a sound agricultural practice, but is subject to criticism when pressure of the population demands more intensive methods.

Agriculture, the oldest of the world's industries, has proved a stern task-mistress. Over the centuries, man, be he educated or uneducated, rich or poor, has found the task of the farmer fraught with difficulties. Two thousand years ago, Virgil, a great Roman poet, retired to his farm to write, and if his immortal quotation is any criterion, did not find the life as easy as anticipated. His words are worthy of reproduction, viz.:

" Pater, ipse, colendi haud facilem esse viam voluit " or in our words " The great father, himself, ordained that the way of the farmer should be, by no means, an easy one."

We of the twentieth century, despite our modern machinery and the achievements of science, still have to contend with the heat and humidity of the tropics, density of vegetation, poverty of the soil, hurricanes

and floods. Diseases and parasites attack our domestic animals whilst we, ourselves, do not escape from the discomforts of tropical illness. It behoves us therefore to give full consideration to the agricultural practices of the indigenous people before replacing them with systems which may not suit the people.

In designing an agricultural system for indigenous people many factors must be considered. The customs, standard of education, traditional diet, aptitude for agriculture, and the social obligations of a people merit as much attention as do purely monetary considerations such as the planting of crops which sell readily. An understanding of the social system of a people is a pre-requisite of a successful agricultural programme. However primitive the working tools may be, a suitable management plan may be evolved if social considerations are not entirely disregarded. As originally designed the traditional systems of shifting cultivation were sound as the resting period was sufficiently long to allow the soil to regenerate its structure and its humic and nitrogen contents. In short it was framed for subsistence agriculture. It follows, therefore, when the resting period is reduced, or the land is continually cultivated without the addition of manures a decline in soil fertility is inevitable.

In certain parts of Fiji, where there is obvious competition for land, the period under bush fallow has been appreciably reduced. In such areas increasing pressure of population will result in the evolution of some form of intensive cultivation by the farmers themselves, and where manuring is part of their agricultural tradition the improvement and modification of their original system may be practically without active intervention. The intensive system which replaces shifting cultivation must ensure the conservation of the soil and the maintenance of its fertility, and if a tradition of manuring does not exist then active intervention is essential.

Despite the undesirable habit of burning off the land in his search for wild yams, the Fijian has traditions of soil conservation not only in his realization of the need for a bush fallow after a period of intensive cultivation, but in his method of planting his food crops on the triangle to minimise soil movement and in the construction of terraces. In addition he appreciated the value of a mulch. The transition from his traditional methods to a modern conception of agriculture may be less difficult if these inherent customs are carefully studied.

The Fijian has from time immemorial used a system of shifting cultivation, which has involved polycultural practices. The writer does not pose as an authority on the traditional agricultural methods of the indigenous people of this colony, and would welcome additional information and criticism, but feels that in view of recent agricultural developments, the known planting methods of the Fijian should be placed on record. He further considers that an appreciation of these agricultural methods may assist in the formulation and successful introduction of rotation systems which may suit the Fijian way of life and therefore have a reasonable chance of survival.

Prior to the advent of Christianty, there was no calendar available to the Fijian. Natural phenomena were his only guide, and an examination of the Fijian year, which was divided into eleven distinct seasons, may be of interest. In analysing this primitive calendar, the writer has assumed that the weeding period was regarded as being the first season of the Fijian year.

(1) *Vulai werewere* (*June and July*).= The season when the food gardens were weeded.

The calendar issued by *Na Mata* shows this period as coinciding with the month of June, but the view of the Methodist Mission and Seeman that the Fijian weeded his land, selected for planting, during the months of June and July is regarded as being more correct. The selected areas were cleared by sharpened hardwood clubs made of vesi (*Instia bijuga*), but in the province of Nadroga, stone axes were also used. The chief, with the advice of the elders, directed all the activities of the clan, including agriculture, and meetings of mataqali (clan) were held before planting programmes were organized. The Turaga ni Mataqali (leader

of the clan) was responsible to the chief for all plantings done by the mataqali members.

After felling the trees, shrubs, reeds, etc., the heaped up rubbish was burned, the flame being induced by rubbing a vau (*Hibicus tiliaceus*) or sama (*Commersonia echinata*) stick, against a similar log. Sauvata or tavata, which were roughly constructed contour banks, established by piling the reeds, logs, and rubbish left after burning on an arbitary line drawn across the slope, were then constructed. On steep slopes, one or more of such banks were built. Balabala (*Cyathea lunulata*) and other trees were placed along the contour line, and Vasili (*Cordyline* (*Tætsia*) *terminalis*) or Lata (*Coleus* spp.) and occasionally Vudi (*Musa paradisiaca*) planted to mark contour. It is interesting to note that Field Assistants, when marking out contour lines, still use Vasili as a permanent plant on the line.

Special kinds of yams such as Rausi, Kasokaso, and Irisi, which were the largest and softest varieties grown especially for presentation to the chief in the vulai sevu were planted immediately above the sauvata.

(2) *Vulai cukicuki* (*August*).=The season when the yam gardens were prepared and planted.

The planting programmes of the Fijians were determined by the flowering times of various trees and not by phases of the moon as suggested by various authorities. Although crops such as dalo (*Colocasia antiquorum*), breadfruit (*Artocarpus communis*), bananas (*Musa sapientum*), Vudi (*Musa paradisiaca*), and coconut (*Cocos nucifera*), flourished in Fiji, the yam was the most important food crop and its cultivation and ripening seasons were the chief foundations of the native calendar. The most popular type was *Dioscorea alata*. Linn., many varieties being recognized and grouped under the name of " Uvi ".

The flowering of the Drala (*Erythrina indica*) which takes place in July and early August, was the sign for planting to commence. Using long sharpened staves called " Doko " or "Ai Sau ", mounds (Bukebuke) about two feet high and four to five feet apart were prepared. Yam sets were planted on the top of these mounds and Yaqona (*Piper methysticum*) at the base. Yams were not planted in rows but in a triangular or diamond shaped manner in order to reduce soil movement to an essential minimum. Dalo and Vudi were interplanted being spaced three-four feet and four-six fathoms respectively, the wide spacing of the latter so that the annual crops would not be unduly shaded. After the arrival of the European, water melons were planted where the rubbish has been burned, and maize was often interplanted, but not until the yams and dalo had struck, so that the maize stalk would act as a support for the growing yam. Varasa ni Viti (*Allium ascolonicum*) would be planted out on the edges of the drains, as it matured quickly in such locations.

(3) *Vulai vavakada* (*September*).=The season when reeds to support the yam stalks were set out in the gardens.

If the yam stalk had grown too rapidly, the reed was bent over to carry it over to another carefully placed reed, so that not only would the plant be adequately supported, but that weeding would be easy, the rapid growth of the yam would not interfere with the progress of the yaqona, and the stalk would not be damaged by heavy winds. The grass was spread out between the mounds and acted as a mulch for the dalo. If, however, the yaqona has not germinated at the time of the weeding, the set was covered with grass to keep cool and moist. A similar practice was customary in Tonga.

(4) *Vulai Balolo lailai* (*October*).=The season when the Balolo (*Palolo viridis*, Gray) made its appearance in small numbers.

(5) *Vulai Balolo levu* (*November*).=The season when this animal was seen in large numbers. The 25th November is the day when it is most plentiful.

The arrival of the Balolo was anxiously awaited and most accurately predicted from the phases of the moon. Its advent in addition to bringing a much esteemed food, marked the time when the yams, which would satisfactorily reach maturity, could be easily recognized. The yams which would not yield satisfactory tubers lost their leaves during this period, whilst those which had progressed, and would give

good yields, flourished until the Vulai kelikeli (March) when they were harvested. Scarcity of Balolo indicated that the yam crop would be below normal, whilst its presence in large numbers was a good omen for the coming harvest. After it was cooked, rain to put out the fires was anticipated, and its non-arrival meant that the yam crop would be poor.

(6) *Vulai Nuqa lailai* (*December*).=The season when the nuqanuqa (*Decaspermum fructicosum*) commenced to flower and its blossoms were present in small numbers.

(7) *Vulai Nuqa levu* (*January*).=The season when this tree is in full bloom.

Seeman erroneously called these the periods when the Nuqa (a fish found in Fiji waters) makes its appearance in isolated and great numbers respectively. The flowering of the nuqanuqa tree marked the time when yam tubers had formed.

(8) *Vulai Sevu* (*February*).=The season when the first yams (ai sevu) were dug and presented to the chiefs and betes (priests).

In Bau only offerings of yams were made, but in other parts of Fiji, such as Beqa, other crops in addition to yams were presented.

(9) *Vulai kelikeli* (*March*).=The season when the yams were harvested and stored in specially constructed sheds. This period was marked by the flowering of the reeds.

(10) *Vulai Gasau* (*April*).=The season when the reeds began to sprout afresh. The Fijians did not like this time of the year, as during this period such as Molilecau (*Citrus sinensis*), moli kana (*Citrus maxima*), moli kurukuru (*Citrus* spp.) and dawa (*Pometia pinnata*) were attacked by the indigenous fruit fly (*Dacus passiflorœ*).

(11) *Vulai Doi* (*May*).=The season when the doi (*Alphitonia zizyphoides*) flowered. This was the time when the vuci or irrigated terraces were planted with dalo.

Fijians had other names for periods of the year which had special characteristics:—

Vulai Vila or Vulai liliwa.=The time of the year when the crops did not mature satisfactorily, e.g. the fruit of the banana were thin and dalo showed little growth during this period. It corresponded with the colder months of the year.

Vulai Ratu or Vulai Ratumaibulu.—Marked the time when Ratumaibulu, who was the God of the crops, came to the earth. He was the Fijian equivalent of Ceres or Demeter, and arrived on earth during November and December causing the fruit trees to flower and making the season bountiful. During his visit people kept very quiet, and did not make unnecessary noise for fear that he would be angered and leave the earth before completing his work. It was "Tabu" (forbidden) for any one to sail, make war, or plant during his time on earth. Ratumaibulu departed at the end of December, his departure being announced by a loud clap, and labour was again permissible.

The season when the yams were ready for digging was sometimes called Vulai botabota or vulai magomago implying that the leaves were drying and that the plants had matured. In the case of yams the leaves would turn a reddish yellow colour. The Vulai botabota would probably coincide with February, and the Vulai magomago would be one month later.

The Vulai teitei or planting time was the period from May to August, Vulai uca, the wet season, and vulai raurau, the time when conditions for planting were unsuitable.

Direct sunlight in the tropics adversely affects soil productivity, especially on soils originally developed under natural shade. The Fijian was well aware of this fact, and called soils which had been thrown out of cultivation because of reduced fertility, and which were unprotected by secondary jungle, "qele talasiga or qele dravuisiga", meaning earth which had no protection from the sun's rays.

The agricultural system of the Fijian, primitive as it was, worked to a set programme, and was by no means a haphazard and indiscriminating planting of a variety of crops when and if the operator felt inclined, but a cleverly devised and well supervised cropping programme, suitable to the conditions and peculiar circumstances existing at the time.

The early authorities on agricultural conditions in Fiji make no mention of indiscriminate firing of land. This habit has become very serious in recent years, and despite the efforts of provincial authorities has been most difficult to control.

A system of shifting cultivation becomes dangerous when grasses such as Imperator spp. invade the bush fallow. Natives burn the open woodland in their search for wild yams and small game, the vegetative cover on the land is moved, and soil erosion is the inevitable result. The Government Entomologist advises that in New Guinea, where similar agricultural practices are extant, vast areas of secondary jungle are destroyed annually by natives in search of wallabies and other small animals. Kunai (*Imperata arundinacea*) invades the area after burning, and forest bordering the open country is damaged annually by the fires. Analysis of Kunai have shown that the plant is a very heavy potash feeder. Indiscriminate firing of land has caused much damage to lands in the province of Macuata. In 1860, Seeman referred to this province as being the most productive in the group, and readers familiar with the dry zone of Vanua Levu, would question this statement had it been made by some other authority. It is worthy of mention that the name Macuata means a surplus of crops, and it is possible that the original name of the province was Macu i Vuata (surplus of crops). The impoverishment of soils in Macuata is not due entirely to the agricultural system of the people, but rather to the need for increased production after Cession. The system was devised for subsistence agriculture and the establishment of Government in Fiji made the agricultural produce of the Fijians attractive, and a source of money to the people. It resulted in the system being overtaxed, and as the years went by, the control of the chief, which was so necessary for the successful operation of the scheme, diminished.

Similar systems of shifting cultivation were in use in other Pacific territories. In Samoa, the breadfruit, (*Artocarpus communis*) was regarded as the most important food crop, while the agricultural economy of the Hawaiian group revolved about the dalo or taro. The Tongans, whose planting programme was based on the cultivation of the yam, have devised a unique system of land ownership and utilization.

On attaining 16 years of age, a Tongan male may apply for a grant of 8¼ acres of land as a tax allotment and in addition, a residential block not exceeding one rood twenty-four perches in area. The rental of the agricultural block is eight shillings per annum, payable either to the Crown or the holder of the estate. In 1941, every Tongan was required by law to plant up to half his area with coconuts and specified quantities of food crops. A specimen planting order is shown hereunder:—

Crop.	Number of plants which must be planted.	Date on or before which planting must be completed.
Ufi (Yam)	600	31st December.
Talo (Dalo)	150	,,
Manioke (Cassava)	200	,,
Kupe (Arrowroot)	50	,,
Sione (Bananas)	100	,,
Hopa (Plantains)	10	,,
Kumalas	300	10th June.
Koane (Corn)	100	,,
Kaho (Vau) Hibiscus tiliaceus	10	,,
Kava (Yaqona)	10	,,
Au (Reeds)	50	,,
Hiapa (Nasi)	100	,,

The traditional agricultural methods of the Tongans were based on a bush fallow, and differed a little from the Fijian system. Yams were planted, and food crops intercropped with them for two to four years, after which the land is reverted to secondary jungle for six to twelve years.

In Burma, India, Sumatra, Philippines and Malaya a method known as Kaingining has been used with considerable success. This is, in effect, a long term rotation wherein the land is occupied for a certain number of years, by either the original or successive growths of forest as a cover crop. Having selected an area for Kaingining, the jungle is slashed just before the arrival of the monsoons. The larger trees are ringbarked or lopped, but no stumps removed. The soil is neither ploughed nor dug and annual crops are dibbled in to the land, after the rubbish has been heaped and burned. As soon as one crop has been harvested, the land is allowed to revert to jungle to prevent the rapid growth of undesirable weeds. A new area is then selected and the process repeated, the abandoned land remaining under bush cover for five to twenty-five years depending on the locality.

Interesting rotation systems based on this method have been evolved. In Sumatra, wrapper tobacco of the finest grade has been produced in Kainginings, one crop of tobacco being rotated with seven years of secondary growth and teak which has been harvested for seven year old poles before burning the cleared land. Similar practices have been successfully initiated in other countries by clearing the land, planting a food crop, and at the same time establishing economic trees, such as rubber and tung oil. The trees when established require circle weeding regularly to prevent them from being smothered by the encroaching jungle.

A modified system of shifting cultivation has been evolved in the Belgian Congo. This method whilst conserving the soil has proved attractive to the people. Dr. Charles E. Kellog, when discussing this method known as the Corridor System, stresses the need for the alternate use of land for crops and forest with the prevention of savanna invasion. He considers that the cropping system should be so arranged that the surface of the soil is shaded from the sun as much as possible. The treeless slopes and plains of Macuata and Bua bear silent testimony to the accuracy of these statements.

An area of land is divided into long corridors, 1,000 to 2,000 yards long and 300 yards wide. A corridor is needed for each year of cropping and each year of bush fallow, so that if six years of rotation of crops with 12 years of forest growth was planned, 18 corridors would be required. This should be so arranged that the forest in some stage borders each corridor. Each year one corridor is cut, the bush being burned, but the logs left to rot in order to add organic matter to the soil. Various combinations of crops would be planted. A suggested cropping arrangement is commenced by the planting of maize, rice, cassava and bananas. The maize is harvested followed by the rice and cassava and finally bananas at the end of the third year. Peanuts or kumalas are grown in monoculture followed by another combination of cassava and bananas or some other crop of a shrubby nature. The forest growth is then allowed to grow over into the corridor under crop. After 12 years the cycle is repeated. Peanuts grown in monoculture are regarded as being unsuitable for the termination of the cropping programme as they encourage the growth of savanna.

It would appear that a controlled system of polyculture, such as that described by Dr. Kellog, has obvious advantages, and may be suitable for tropical countries where pressure of population does not constitute a serious problem. But in closely settled areas where more intensive methods are inevitable it obviously requires modification. In parts of Fiji where there is competition for land, the Fijian, particularly the individual farmer, is gradually learning to farm his own land, and for the transition from shifting cultivation to more intensive methods to have the desired results, he must consider the incorporation of proved methods of restoring and maintaining soil

fertility in his agricultural programme. Included in these methods are such practices as rotation of crops, temporary leys, mixed farming envisaging the utilization of crop residues, the use of the animal droppings, compost, etc., green manuring and the use of artificial manures. In describing the agricultural practices of the Fijian and comparing them with similar and improved methods, the writer has been actuated by the desire to place the known methods on record and to show that they had much to commend them.

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STACK SILAGE IN TAILEVU

BY A. D. MERCER, DIP. AGRIC. (READING).

It is usual in Fiji for the period July to September to be a season of feed shortage for most dairy herds. Growth of para grass is almost at a standstill while the mixed pastures have generally reached the stage where cattle can find only a picking of herbage. Costly supplementary feeding with concentrates has therefore to be resorted to, but it is doubtful whether the average herd is receiving sufficient bulk of feed at this time of the year. It is only reasonable to assume that the feeding of surplus growth, conserved as hay or silage, would help to carry the herd over the difficult period. Hay making being impossible, at least in the south-eastern districts of Viti Levu, silage is the only alternative, and of the various methods of making it, stacking, for a number of reasons, is most convenient to the dairy farmer. The making of stack silage had never been tried in Fiji, but in the summer of 1949 Mr. W. Gatward of Korovou, Tailevu, decided to make the attempt.

Early summer growth, when the herbage is in the young nutritious stage, is necessary for good quality silage, but there was insufficient surplus feed early in the season to allow of shutting up an area, and it was not until the end of January that a 14-acre field was closed to stock. By the beginning of March the area was fit for mowing, but incessant heavy rain and flooded rivers made it impossible to commence operations until the end of March, a month after the material had reached the best stage for cutting. On the 14 acres the herbage consisted of sour grass (*Paspalum conjugatum*), carpet grass (*Axonopus* spp.), other inferior species of paspalum, sensitive plant (*Mimosa pudica*), *Desmodium* sp. and various annual weeds including mile-a-minute (*Mikania micrantha*). Mowing commenced on the 28th March and stacking also started on the same day. Bullocks were the only power available for the mower, sweep and sledges, and in the absence of stacking equipment, all material had to be forked from sledge to stack. Sufficient material was mown each morning for the day's stacking, and operations lasted for seven days. Heavy rains at times made for slow and laborious work but the stack had heated sufficiently each morning to allow further stacking to proceed without delay. Two men were on the stack constantly, and each morning it was given a good tramping by all hands to ensure consolidation. The stack was circular, 20 feet in diameter, and when completed, 18 feet in height, containing 50 to 60 tons of material. Earthing up proceeded as soon as the last load was stacked, but a thin coating only of earth was put on, as the

only means of getting it up to the top of the stack was by hauling it in buckets, a slow and heavy job.

The cost of the silage worked out at 10s. per ton, but the time taken, and therefore the cost, could be very considerably reduced if suitable equipment were available. The quality of the material ensiled left much to be desired; it was overmature and woody, while its spongy nature, due to the presence of sensitive plant, mile-a-minute, and other weeds made it impossible to achieve the degree of consolidation that can be attained with purely grass material, and which is necessary to exclude air and prevent overheating or mould formation.

The stack settled finally to a height of ten feet and was opened in August by cutting down a segment. Wastage on the top and sides was slightly above the average for a good stack, owing to the open nature of the material. The silage in the upper portion of the stack was of the sweet, dark brown type produced by overheating, but lower down, where consolidation improved, an acid, light brown silage was reached. It was found however that the cows would not take to it, doing no more than pick it over, even with the addition of molasses. This may be accounted for by the fibrous nature of the material and the fact that even in the cool weather there is in Tailevu a certain picking of green grass growth.

It is evident however from this trial that stack silage can be made successfully in the tropics, but that successful utilization is more likely to be achieved in the dry zone of Viti Levu during the period when no green feed is available, and if the material employed is cut at the young leafy stage of growth.

ANIMAL HUSBANDRY . . .

SOME ASPECTS OF DAIRYING IN FIJI

BY H. T. B. HALL, B.V.Sc.

(PAPER READ AT THE 7TH PACIFIC SCIENCE CONGRESS, 1949).

1. INTRODUCTION.

The progress of the dairying industry and its present economic position has been a subject which lately has caused some concern to the Government of Fiji in view of the increasing costs of, and decline in, production and the deterioration of pastures.

With a view to obtaining reliable information on the economics of the industry and to discover the reason for the decline in production a survey was recently undertaken and the results of that survey together with a general outline of the industry as it is today form the subject of the present paper. The multiplicity of reasons discovered to account for the general deterioration are, of course, closely connected, but a description of a few of the more obvious factors serves to point the way to the lines of improvement which are being developed, experimentally in the first instance with Government backing, and which it is intended should be subsequently used as a guide by dairy farmers in these islands.

Already provision has been made by the Government of Fiji for the application of findings from other tropical areas to local conditions, for the modification of such findings to suit these conditions and for increasing the facilities for the farming public to take advantage of the improved methods which are to be expected and, although it is too early as yet for any data accumulated so far to be complete enough to be made available to the public, sufficient information is already available to indicate that the work is proceeding along the right lines.

It is to be recalled that tropical butterfat farming is a comparatively modern undertaking and the development of suitable animals and foodstuffs is not at the stage of such work in temperate countries. That there is a very real difference between the two types can scarcely be denied since one has only to see the temperate breeds of livestock in really tropical countries to realise that such animals will not function to give an economical return without some modification. The same may be said of the food that such animals eat. The following notes may serve then to indicate the difficulties which have been encountered in Fiji and the work progressing to determine how these difficulties may be overcome.

2. HISTORY.

Dairying for the production of butter on an economic basis commenced in 1921 ([15]) when the Government of Fiji at that time agreed to finance a number of returned soldiers in establishing dairying at Tailevu, an area some 30 miles from Suva, consisting of alluvial flats on the banks of two converging rivers and the adjacent hill lands. Subsequent development by the original settlers was very variable, a great deal depending on the farmer himself, but there were many other factors which prevented a successful development of this scheme, such as the difficulty of obtaining suitable livestock and the lack of adequate transport. A factory was erected at the centre of this area and in eight years production rose from 13,104 lbs to 313,655 lbs of butter which was the figure reached in 1928. This was not all produced from the original 20 holdings but included the production from six independent producers who had changed over from banana growing.

At the same time as the above development was taking place in Tailevu, a company was formed and took over a large area of land at Navua which had been used for sugar growing. In 1924 this company, ([7]) with the additional supply of some five or six independent dairy farmers, established a factory in the building which had been the sugar mill and in 1932 produced 125,587 lbs. of butter([8]).

In 1924 a third factory was established at Rewa [13] with supplies drawn mainly from the Rewa Delta, the Waidina, and Vunidawa river flats.

In 1929 Stuchbery[13] records that 52 herds were supplying cream to factories, but states that a large proportion of the milking stock were unprofitable, having been drawn from untried stock. The butter production for that year was 392,214 lb[16] but there is no record of the number of cows concerned with that production.

In 1930 the industry had reached the stage of completely filling the local demand for butter and a commencement was made on the export of butter to the United Kingdom. There, of course, and particularly at that stage of the world depression, the Fiji butter had to face such competition from other countries that a reasonable return to the farmer could not be obtained and in 1933 all butter surplus to local requirements was converted to ghee (clarified butter) and sold locally.

In 1933 the Tailevu factory was closed down[17] and cream from the district was delivered over a newly built road to the Rewa factory. The reason for the closing down of the Tailevu factory was that with the small amount of cream operating costs were too high, a trouble which the two other factories were experiencing and with the amalgamation of Tailevu and Rewa operating costs were reduced considerably.

From the early 1930's the actual production of butter and ghee steadily rose until 1938 when 523,759 lb of butterfat were produced.[18] Unfortunately there is no record of the number of cows or the area or type of pasture concerned with that production, but the figures given refer to butterfat processed to either butter or ghee in the two factories then operating, and not to ghee production by peasant farmers. This ghee production, of course, was quite impossible of accurate assessment and, in fact, to date no system has been devised whereby this could be reasonably accurately assessed.

During the war years production receded to 441,857 lb (1946)[4] due to lack of labour and consequently the encroachment of weeds and deterioration of pastures generally, but with the return to more normal conditions, rehabilitation of pastures has halted this recession and the last available figure for 1947 is 480,524 lb of butterfat[5].

It is to be noted that the figures quoted refer to overall production of butterfat processed through the factories operating in Fiji. Variation in production per cow or per acre will be referred to subsequently in this paper.

Very little has been recorded on the type of pasture which was used in the earlier years of the industry but it is known that para grass (*Brachiaria mutica*) was the main pasture, with good stands of *Paspalum dilatatum* and *Panicum maximum*. Sensitive plant (*Mimosa pudica*) was established on most grazing areas but its value was doubted because of its apparent unpalatability.[20] *Axonopus compressus* and *Paspalum conjugatum* were common grasses of the hillside.

3. ECONOMICS OF THE DAIRYING INDUSTRY.

From figures available from the recent survey it is apparent that dairying at the present time in Fiji is not a highly profitable undertaking for the average European farming as an individual. Production per acre and production per cow have deteriorated, while costs for labour and maintenance have increased by more than double since pre-war days.

The farmers included in the whole survey were grouped into three different categories. Group 1 includes all farmers who have dairying for butterfat production as their major source of income and who produce more than half of the total butterfat. There were 29 farmers. Group 2 includes six Fijian and Indian farmers who occasionally supply butterfat to factories and obtain their main income from other sources. Group 3 includes a single company, the Fiji Pastoral Company who maintain 13 separate dairy farms, all contiguous and all supplying the company's own factory, the whole being under a single management. It is clear that Group 3 with three men and their families to be considered, could not be

included with Group 1 with 29 men and their families. Group 1 is the only group dealt with in this paper from the economical aspect, but information from the other two groups is included in the other parts of the paper.

Some figures resulting from the survey of Group 1 and discussed in this paper are given in tabulated form as follows:—

	Total	Per Farm	Per lb of butterfat
	£	£ s. d.	
Labour—			
Field	5,558	191 14 0	4·848d.
Milking	7,519	259 4 0	6·531d.
Fuel, feed, repairs and maintenance	6,422	221 8 0	5·575d.
Rental, insurance and interest ..	4,925	169 8 0	4·278d.
Profit	5,055	174 6 0	4·389d.
Total ..	29,479	1,016 0 0	25·621d.

Total butterfat produced on the 29 farms	276,404lb.
Total number of cattle	4,893
Average butterfat production per cow ..	98·75lb.
Numbers of acres used for grazing ..	6,800
Average butterfat production per acre of used pasture	40·65
Grazing capacity of land used for mature cows acres per cow.	1·52

Of the 29 farms of Group 1 the average annual production per cow is 98·75 lb. It is regrettable that production of each cow per lactation and the length of each lactation cannot be obtained owing to lack of available data but the latter is considered to be very little under once per annum.

The average net income per farm from butterfat is £174 6s. and the net return per lb of butterfat is 4·39d. These figures are arrived at as follows:—

The annual expenditure consists of rental, insurances, labour, fuel, feed, repairs, maintenance, and interest on capital at three per cent. The annual income was derived from factory returns on poundage of butterfat. Returns for each of the farms were taken out separately. The value of capital invested was arrived at by normal valuation methods, and included values for buildings, livestock, fencing, equipment, and pasture.

Twelve farmers maintained pigs, and/or poultry as a subsidiary to dairying and if the proceeds from these are included, their annual income becomes £244 8s. Labour and materials, fuel, feed, etc., used for pigs and poultry, are already included in the annual expenditure figure. If the income from all three sources is related to the return per lb of butterfat this figure becomes 6·154d.

It is realized that in this survey some of the information obtained was not absolutely accurate since farmers in the survey did not keep a full set of accounts, but checking of figures was carried out wherever possible and it is considered that the figures given are sufficiently accurate to be very useful in assessing the economic position of the industry.

The most serious factor in preventing a more profitable return was the large amount of labour required in eliminating weeds from pasture. The amount expended on labour for pasture, fence, and drain maintenance amounted to £191 14s. per farm or 16s. 5d. per acre. The average number of acres in use per farm is 234·5. The butterfat per acre is 40·65 lb and it appears that farmers are losing a little under 5d. per lb on pasture, fence and drain maintenance, of which approximately 80 per cent is on weed elimination alone.

Very little heavy mechanical equipment is used on these farms, due to lack of sufficient capital to meet the heavy expenditure involved and to the fact that in the cases where capital is available no suitable equipment is obtainable, but without mechanical equipment and with the inefficiency of field labour in eliminating weeds manually, the heavy expenditure of weed elimination will continue to be a drag on the economy of these farms.

Another heavy expenditure is labour in milking cows, and here again the inefficiency of manual labour is clearly exemplified. It costs 6·531d. per lb of butterfat. The actual number of cows milked by each labour unit, 20 to 25, is reasonable, as judged by non-European standards but with the low production per cow the cost per lb of butterfat is obviously out of proportion. Milking machines were in use on only two of the 29 farms and even on these two the

saving in labour was not marked, since the labour for attention on the machines was little less than the labour required for milking the cows by hand. Stripping was practised in both these cases.

Fuel, feed, repairs and maintenance, accounted for £221 8s. per farm or 5·575d. per lb of butterfat, which is reasonable but it is to be noted that very little hand feeding of cattle takes place, not that farmers are apathetic about it, but because the cost of feeds is so high that farmers cannot see an economical return from feeding it to the type of animal which they have.

It is to be noted also that there is practically no expenditure on fertilizer, a position which, no doubt, is astounding to many temperate climate farmers. Here again there is some justification. A farmer cannot afford to experiment, and as yet it has not been determined what fertilizers are required and the quantities which can economically be used. Work, however, is proceeding and results will soon be available. It will remain then to find an economical way of fertilizing these areas.

Rental, insurances and interest on capital are reasonable and account for the remainder of expenditure. They amount to £169 8s. per farm or 4·278d. per lb of butterfat. Thus for a total expenditure of £841 14s. per annum a farmer gets back in return £174 6s. or 20·7 per cent on his annual outlay. A better return is obtained from other occupations.

4. DESCRIPTION OF DAIRY FARMING IN TAILEVU.

Sufficient has been said to indicate that at least as far as the 29 farms under discussion are concerned a drastic change of method is badly needed. Let us examine these farms and the methods used and compare them with other methods both local and overseas.

Soil Types[12].—Generally speaking dairy soils of Fiji are confined to the alluvial flats and dissected plains. The following are the most important soil types.

1. *Intrazonal.*—Meadow (Riverside) Soils —waterlogged, with a B–horizon of gleied (mottled rusty) clay and including some of the alluvial soils mentioned earlier, they lie in the 100 to 200 inch rainfall zone.

2. *Azonal.*—River Alluvium—varying from coarse-fine gravel to coarse-fine sand, coarse-fine silt, silty clays and silty loams. This type and type 1 above make up the "meadow alluvials" which are the flat lands of dairy farming.

3. *Zonal.*—Tropical red-brown clays and clay loams with a medium to very deep profile. They were associated with sub-tropical rain forests and tall bush which has been cleared leaving an area of gently sloping but well drained hill country. These soils are readily erodable and where the slopes are steeper the "A" horizon is often non-existent, having been washed away.

All three types of soil are low in phosphate the zonal type being very deficient. Reserves of phosphates may be made to become available on the alluvials by liming and drainage. The lime requirements are high, the alluvials varying in pH from 5·0 to 7·0 and the zonal type from 4·8 to 6·4.

It is clear from the above that dairy farming cannot continue on such soils by the antiquated system at present prevailing. When it is recalled from the recent survey that no allowance is made for top-dressing and the cost of drainage or drain maintenance is only a minor one it is not to be wondered that conditions have deteriorated to such a marked extent in these areas. We shall not have to look far to see other factors which have contributed to this deterioration.

Pasture.—Grass pasture is generally mixed although para grass (*Brachiaria mutica*) still predominates where it is not over-grazed. Under such circumstances it will form para stands, the rank lush growth preventing competition. It prefers the wet conditions prevailing, and its persistence is such that it is considered a weed in areas where it is not used as a pasture grass.

Sensitive plant (*Mimosa pudica*) is used widely although the carrying capacity from this is not very great owing to its prickly habit which prevents cattle from grazing more than two or three inches of the tip. It is a legume, however, and can be seen in association with rough grasses on hillsides. It forms a large proportion of the sward where para grass has not been properly maintained on the flats.

Paspalum dilatatum is now seldom seen. It does not stand up to the constant grazing to which these areas are subjected. Its place has been taken by two other poorer grasses, carpet grass (*Axonopus compressus*) and sour grass (*Paspalum conjugatum*).[14] Seed grass (*Chrysopogon aciculatus*) which, because of its exceptionally fibrous nature[11] can be regarded as a weed rather than a grazing grass is very widespread in non-para grass areas. Owing to its low habit, prolific seed production and low palatability it will establish itself where other grasses are rapidly eaten out and consequently cattle are often forced to graze it in the absence of more nutritious and palatable types.

A creeping plant, *Mikania micrantha*, which, owing to the rapidity of its spread is locally known as mile-a-minute, is sometimes grazed. It has an extremely low protein content[14] with no other compensating advantages and although it makes up some small part of the grazing can only be considered as a weed.

This then can be considered as the common pasture of these farms and it is not to be wondered why production is so low. Add to this the surprising weed population and it is, in fact, remarkable that dairy farming can be maintained. A few of the more predominant weeds are *Solanum torvum, Urena lobata, Stachytarpheta urticæfolia, Cuphea carthaginensis, Psidium guayava, Lantana camara* and *Clidemia hirta*. The last named, although once such a curse that many farms had to be abandoned and which grew so thickly that cattle were unable to press through it, has now been brought completely under control due to the remarkable work of Simmonds with the thrips *Liothrips urichi*.

The predominance of weeds and of poor grasses can no doubt be attributed to lack of an adequate rotation, and over-stocking. Examples are many of cases where due to lack of fencing wire more than to lack of sufficient capital to buy it, the small amount of subdivision which in the past had been carried out has been impossible of maintenance. There is now according to results of the recent survey in the Tailevu and adjacent areas, two chains of fencing per acre of grazed land, scarcely sufficient for an adequate rotation.

Fodder cropping is restricted to calves, and consists solely of closing off one or two small paddocks of para grass and hand cutting. Although excellent fodder grasses can be obtained e.g. Elephant grass *Pennisetum purpureum*) and various sorghums, the cost of growing and cutting without the assistance of mechanical equipment is considered to be uneconomical, with the type of animal being used.

Lack of seasonal farming.—The bull runs constantly with the herd, although dry stock and heifers are kept separately from the milking herd. There is as a result, "all the year round" farming with a fluctuation upwards and downwards of about 20 per cent according to the season of the year. This fluctuation is purely climatic and is a direct measure of individual cow production. It bears no relation to the number of cows milked; this remains practically constant throughout the year. Only in one case has an effort been made to control calvings so that production and the flush season coincide. In this case, although it has only been carried out for two years, results have already proved the value of the practice.

Production at Navua compared to Tailevu.—The foregoing may be taken as a system of dairy farming which has grown up through trial and error, a system which the farmers of the area have devised to suit the conditions of climate and environment and which has been suitable enough to give them an income and a mode of life satisfactory to their requirements in the past. It does not, however, fulfil the requirements of the present day, and to give a comparison with the foregoing a description of the improvements carried out by the Fiji Pastoral Company over the course of their operations at Navua would be appropriate. This company controls 6,000 acres of rich alluvial river flat, the most of which is under dairy farming. The area is divided into 13 separate dairy farm units, all contiguous and all supplying butterfat to the Company's own factory, the whole being under a single management.

With the comparative lowering of overhead costs and greater efficiency natural to a closely integrated organization this company has been able to continue at a profit, and, since the war years expend a considerable sum in rehabilitation of pasture land. Fencing, weeding, and draining have always been maintained at a reasonable standard; great care has been taken to see that no over-grazing takes place; a proper system of herd testing has been practised continuously. Strangely enough, some of the well known improvements common to other countries have not yet been instituted or at least are only now in process of being instituted. Examples are top-dressing of pasture, the rotation of para grass pasture on an adequate basis, control of bull services, and calf husbandry.

According to figures given by the Department of Agriculture and quoted by Sir Maynard Hedstrom, the managing director of the company in 1932,(6) the 774 cows then on the property produced 125,587 lb of butterfat, an annual average production of 162 lb per cow. The production of this herd which had increased to over 1,100 by 1945, and which by drastic culling was reduced to 837 by 1947 showed an average of 169 lb for a lactation period of 257 days.

The six best cows in the herd in 1932 produced over 1 lb of butterfat per day for what might be termed a normal lactation and the best of these produced 372 lb in 300 days. They were all Jerseys.

The six best at the present time produced an average of 337 lb in 333 days which is still over 1 lb of butterfat per day. They were all Jerseys except one, a Holstein Friesian. The average test was 5·5 per cent butterfat. The two best herds, Thalia consisting of 67 cows and Batinikia consisting of 71 cows, produced 195·3 lb of butterfat in 308 days and 253·4 lb butterfat in 320 days respectively.

The position at Tailevu and adjacent areas during a comparable period shows a serious decline and whereas in 1924 the average production there is given as 181 lb of butterfat per cow milked (22), this from mixed breeds of cattle, the recent survey shows that these herds average 98·75 lb butterfat per cow per annum.

There is no need to dwell longer on the obvious causes of this deterioration at Tailevu, but recent records taken at Thalia farm, Navua, show clearly the direction which future improvements should take. The Thalia herd consists of fairly highly graded Holstein Friesians bred to pure imported Holstein Friesian bulls for over 20 years, the only other blood in the original herd being Jersey. From April 1945 until the present time careful records have been taken of the monthly production of this herd except for the period September to December, 1947, when the farm was closed for rehabilitation—ploughing, harrowing, planting, and re-fencing but not top-dressing. Until September 1947, the farm consisted of 126·8 acres of fair para grass pasture with very little weed but some sensitive plant, sour grass, and carpet grass. It was poorly drained and had not been cultivated for some five years. It was fenced into five separate grazing paddocks. The soil type is "the meadow alluvials," mentioned earlier.

After draining, ploughing and harrowing the farm was heavily planted to para grass and re-subdivided to give 20 paddocks, 19 of approximately five acres each and one of 20. A comparison of production for the year 1946 and 1948 is as follows:—

Year	No. of Cows Tested	Av. monthly milk production	Av. Test	Av. monthly butterfat	Total herd butterfat
1946 ..	70	476·2	3·4	16·3	1141·1
1948 ..	66	593·1	3·7	21·8	1339·2

The year 1947 is omitted owing to the break of four months when no records were kept, as indicated above.

There appears to be no reason for the increased production other than improved nutrition consequent upon the better utilization of the land. A factor, however, which must not be overlooked is that some of the cows in the herd were changed. To eliminate any variation due to this, the following table gives the production for the periods April to December, 1945 and 1948.

In these periods, which cannot be extended to include the whole of the year owing to the lack of recorded data earlier than April 1945, the herd consisted of practically the identical animals since those that had been replaced in 1946 were returned again to the herd by 1948.

Period April December	No. of Cows Tested	Av. monthly milk production	Av. Test	Av. monthly butterfat	Total herd butterfat
1945 ..	76	473·8	3·7	17·5	1,317
1948 ..	63	596·3	3·7	22·0	1,379·9

It is clear that these animals increased their individual production when replaced on improved pasture and allowing for the fact that this farm is as yet somewhat understocked it is reasonable to expect that the productive capacity of the land is now substantially increased and certainly has always been considerably higher than the production per acre in the Tailevu area. The 1948 season was not an outstanding one and in fact overall production will probably be a little lower than normal.

5. TYPES OF CATTLE IN FIJI.

With few exceptions cattle used in butterfat production are of the European breed (*Bos taurus*) while cattle associated with with ghee (clarified butter) production are part-European and part Zebu (*Bos indicus*). This can scarcely be considered to be due to the suitability of each breed for the type of production indicated, but is because butterfat production is practically all in the hands of Europeans and ghee production is in the hands of Indian peasant farmers. Each prefers the animal with which he is more familiar and with which he has been associated for many generations. Unfortunately Zebus in Fiji are not high milk producers due to the fact that they are not the strain of Zebu usually associated with milk production. [19] They were imported into the Colony originally as work animals and consequently have never been able to compare with European breeds for milk production.

The Zebus most commonly seen are of the Nellore or the Kankrej strain, neither of which can be called a high milk producing strain.

The majority of the Zebu crosses are with Shorthorn, Jersey, or Holstein Friesian, occasionally with Hereford or Black Poll, the two latter crosses being more usually associated with beef production.

There can be doubt that *Bos indicus* shows a tolerance to tropical conditions far in excess of European breeds. [9] [10] The few random tests carried out in Fiji on the lines of the Iberia Heat Tolerance tests of Rhoad have shown that when conditions are sufficiently tropical the temperature and respiration rates of the Zebu do not increase to the same extent as in the European breeds. Work by Bonsma [1] has shown how milk production and, with it, fodder consumption is lowered in the tropics and figures published by the Imperial Council of Agricultural Research [8] have shown how there is a decrease in milk production when the degree of imported blood is raised above 5/8 even though the genetical make-up for milk production may be greatly increased thereby.

The Colony of Fiji is roughly six degrees within the tropics and one would therefore expect that conditions such as those found by tropical workers in other countries would be general. The following tables for humidity and temperature, taken from the records of the Meteorological Office at Suva are from recording stations adjacent to dairying areas.

HUMIDITY FOR JANUARY—1948—NAUSORI.

A.M.	1·0	2·0	3·0	4·0	5·0	6·0	7·0	8·0	9·0	10·0	11·0	Noon
Mean Humidity Per Cent ..	92	94	94	94	94	94	91	85	81	77	76	75
P.M.	1·0	2·0	3·0	4·0	5·0	6·0	7·0	8·0	9·0	10·0	11·0	Mid-night
Mean Humidity Per Cent ..	75	76	79	78	80	83	87	88	88	91	90	92

TEMPERATURE.

Nausori (for last 19 years).

	Maximum.	Minimum.	Mean Temperature.
January ..	85·7	72·5	78·9
February .	86·2	73·1	79·7
March ..	86·2	72·9	79·5
April ..	83·9	71·4	77·6
May ..	81·9	69·7	75·8
June ..	80·2	67·5	73·8
July ..	79·1	66·0	72·5
August ..	78·7	66·6	72·5
September	79·2	67·1	73·2
October ..	80·8	68·7	74·7
November .	82·4	70·0	76·3
December .	83·9	71·5	77·7
Year Mean.	82·3	69·7	76·0

It is apparent from the above tables that conditions of temperature are milder in Fiji than in other countries where an admixture of Zebu blood is recommended ([10]), but the humidity figures given indicate that Fiji is extremely humid. The month of January was selected in view of the fact that this was about the hottest period of the year and there are 597 records for the month incorporated in the table. It is questionable whether the use of any Zebu blood in dairy stock is necessary or warranted but it is quite certain that cattle having a proportion of Zebu blood are never found to be among the top producers on dairy farms, but regrettably enough, no production figures are available for Zebu or Zebu-cross. However, as mentioned previously the strain of Zebu found in Fiji is not a high milking strain; examples of the Sahiwal and Hariana ([19]), both fair milkers, are not to be found in the Colony. It would appear appropriate, therefore, to satisfy the requirements of the Indian ghee producers to import from India one or more of the milking strains of Zebu.

The European breeds found most commonly are Holstein Friesian, Shorthorns, and Jerseys. The marked preference of the majority of farmers for Holstein Friesian is a little difficult to explain in view of the fact that the heat tolerance of the Jersey, for example, appears to be superior([21]) ([23]), and, as indicated earlier, the production of Jerseys appears to be the best in the Colony. One factor which might cause some tendency to prefer Holstein Friesian has been that as far as local Jerseys are concerned there appears to have been a greater susceptibility to tuberculosis. There has been, in any case, a tendency to discard Jerseys in favour of either Holstein Friesian or Shorthorn, the most likely reason for this being that culled animals and steers are often used for beef and, in the case of steers, for work, and the Jersey is not highly suitable for either of these purposes. Recently however, some importations of new Jersey blood have been made and these at the present time appear most promising. As already mentioned the majority of best producers at Navua are still Jersey.

There appears to be no difference in milking value between Holstein Friesian and Shorthorn. Both are popular and both are widespread throughout the Colony. Where improved nutritional conditions have been made available both have responded well.

6. THE PRESENT PROGRAMME OF INVESTIGATIONAL WORK.

Already some progress has been made in investigation aimed at improving the nutritional status of dairy cattle. Two agricultural stations are now established, one of which has been developed as a livestock farm for the last two years and the other, recently established, will have livestock improvement as a considerable part of its activities. One dairy herd has been established and work is proceeding on the feeding of local concentrates, the most suitable rotations of para and other grasses, the use of fodder crops, the development of leys or alternate husbandry, the top-dressing of pasture, as well as numerous other subsidiary lines. An enormous amount has still to be done however, not only on local short term and long term experimental work but also on the local application of overseas findings as a demonstration to the farming public. Naturally the majority of the work will be aimed at improving the conditions of small peasant farmers but most of the findings will be equally valuable in their application to butterfat dairy farmers.

A full programme of investigation would, of course, include the evaluation of Zebu blood for dairying purposes and it is

expected that in due course this will be carried out. For the present, however, the more pressing problem of nutritional improvement must receive first consideration. Fortunately funds have been made available for a full programme of work in this important field.

7. DISEASES OF CATTLE.

Fiji is completely free of the highly infectious tropical diseases of cattle, due no doubt to its isolation and an effective quarantine service. In fact the livestock disease position generally is not by any means of serious proportions. Tuberculosis and endoparasitism are the two main problems.

The incidence of tuberculosis on dairy farms where tuberculin testing is first undertaken varies between 10 and 30 per cent. Where testing has been carried out as a routine measure this is now reduced to between one and two per cent. Approximately half the herds supplying butterfat are now tested and efforts are being made to extend the testing as facilities become available.

Deaths in young stock from parasitic gastroenteritis are very serious and probably account for the marked discrepancy between the number of calves born on dairy farms and the number which reach maturity. An accurate survey of the worm parasites has still to be done, but in the meantime much progress is being made in routine drenching of all young stock. Where this is done deaths are being reduced to negligible proportions.

Brucellosis has been present in the Colony for some years in sporadic or in enzootic form. In the past two years widespread vaccination with Strain 19 vaccine has been undertaken and although no positive indications are yet available to evaluate the control of the disease by this means it is expected that it will be reduced to minor importance.

8. SUMMARY.

The history of the dairying industry is described briefly.

A description is given of the present economic position of the industry.

The type of land suitable for extension of the dairying industry to cope with local demand is limited and therefore increased production must be obtained by more intense utilization and a more scientific approach on the part of dairy farmers.

Methods at present being used are compared with overseas methods and figures are given for local butterfat production.

Types of cattle used for butterfat and ghee production are described and evidence given to indicate the value of British breeds in semi-tropical countries.

Pasture and supplementary feeding on lines indicated by experiments show promise of greatly increasing production.

The disease position in dairy cows is discussed briefly.

9. ACKNOWLEDGEMENTS.

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ENTOMOLOGY . . .

PREMATURE NUTFALL OF COCONUTS IN THE BRITISH SOLOMON ISLANDS PROTECTORATE

BY B. A. O'CONNOR, B.Sc. AGRIC., B.A.

INTRODUCTION.

A short article on this subject appeared in a previous number of this *Journal*(8), and it is now proposed to present a full account of the investigation carried out in the British Solomon Islands Protectorate during the period July-September, 1948. This survey, which was undertaken by Mr. R. Leach, a mycologist, of the Cambridge School of Agriculture, and the author, was initiated by Messrs. Lever Bros., who retained the services of Mr. Leach. At their request, the Government of Fiji instructed the author to accompany Mr. Leach.

The following account owes much to the work of Leach, whose contributions to the joint investigation were of major importance. Free use has been made of his unpublished report,(7) and the accompanying plates have been reproduced from his excellent photographs. Leach has also published a short article on the subject of nutfall,(2) with a number of valuable plates.

OBJECTS OF THE TOUR.

As our stay in the Solomons was to cover a period of only two months, our objective was not so much to solve the knotty problem of controlling premature nutfall, as to advise Messrs. Lever Bros. regarding what further action, if any, should be taken towards such a solution. As pre-war workers had shown the immediate cause of premature nutfall to be puncturing of the female flowers and young fruits by the *Coreid* bug, *Amblypelta cocophaga China*, the author intended investigating control measures for the injurious ants concerned in the problem. It was not possible to attempt field control of *A. cocophaga*, owing to the lack of a power duster. Leach planned to study phenomena such as the occurrence of palms in nutfall areas which continued to bear good crops, even though occupied by harmful ants. As it turned out, the situation in the field was such that both of us spent the bulk of our time in a study of the ant situation.

PRE-WAR WORK ON PREMATURE NUTFALL.

Before describing our work on the problem of premature nutfall, it is necessary to present a brief account of the position as it was before the outbreak of war. Messrs. Lever and Pagden of the Colonial Service, Mr. Cottrell-Dormer for Fairymead Sugar Co., and Dr. Phillips for Messrs. Lever Bros. had all investigated the problem, and had worked out the full story of the cause of premature nutfall, and the influence of various ant species on its incidence. Following is a summary of their findings:—(N.B. the term "premature nutfall" as used throughout this account does not cover minor forms of premature nutfall, such as may be caused by *Tirathaba rufivena*. Nor does it include premature nutfall caused by adverse soil conditions and other physiological factors. It means only the really serious and widespread form of premature nutfall caused by the bug *Amblypelta cocophaga*.)

(i) The immediate cause of premature nutfall is the puncturing of female flowers or young nuts by the *Coreid* bug *Amblypelta cocophaga China*.*

(ii) The large, yellow tree-nesting ant, *Oecophylla smaragdina subnitida Emery*, drives out the bug, so that where Oecophylla is established, palms bear well. Another yellow, so-called "crazy ant", *Anoplolepis longipes Jerd.* has some beneficial effect.*

(iii) The ants *Pheidole oceanica Mayr.* and *Iridomyrmex myrmecodiæ Emery* tend to drive out the beneficial species, but are not themselves capable of suppressing *Amblypelta*. Consequently, where *P. oceanica* or *I. myrmecodiæ* is dominant, premature nutfall occurs.*

* These conclusions were confirmed by Leach in laboratory experiments and in very detailed surveys of plantation areas, involving examination of hundreds of individual palms.

The life-history and habits of *A. cocophaga* were investigated by Lever, ([3 5 6]) Pagden and Lever,([9]) and Lever and Phillips,([7]) and Dr. Phillips subsequently made a study of the bug. ([10 11]) It was found that nuts up to four months old could be caused to fall by the feeding of the bug, and that both nymphs and adults were injurious. Nutfalls on which the bug had fed showed characteristic deep furrows under the calyx. The distribution of *Amblypelta*, as far as was known, was in Santa Ana, San Cristoval, Guadalcanal, Malaita, New Georgia, Kolombangara, Tetipari, Rendova, Ganonga and Vella Lavella, and it had not been found in Choiseul, the Shortland Islands, Ysabel, the Manning Straits Islands, the Russell Islands and the Three Sisters.

Oecophylla was known to occur throughout the B.S.I.P., and its habits were well-known. *Pheidole oceanica* was also widely distributed, and thought to be present throughout the group. *Anoplolepis longipes* was also widespread, (details of its distribution have not been seen) but *I. myrmecodiæ* had not been found in the Russell Islands or further west, though it was present on islands to the east of this point.

The pre-war investigators seem to have agreed that control of *Amblypelta* by mechanical measures was not practicable, and efforts to establish *Oecophylla* in nutfall areas were not successful. Egg-parasites of the bug were introduced from Java, and some work was done on the introduction of *Tachinid* parasites from Australia. However, up to the time of the outbreak of war, little progress had been made in controlling *Amblypelta*.

NOTES ON PRINCIPAL INSECTS INVOLVED.

Amblypelta cocophaga China.—(See Plate 1).—This Coreid bug is mainly light-green in colour, except for the elytra and the hinder part of the prothorax, which are

Plate 1 : *Amblypelta Cocophaga China.* Feeding near apex of 8 week old coconut.

—Photo R. Leach.

Plate 2 : Section of unopened female coconut flower, showing injury to ovary caused by feeding of *Amblypelta*. Abscission of ovary commenced, but no " nutfall ", because outer calyx segments remain persistent.
—*Photo R. Leach.*

reddish brown. The body is about 14 mms. long and 4 mms. wide. It is a sluggish insect, which does not readily take to the wing when disturbed. Its distribution in B.S.I.P. has been mentioned above. The food plants of the bug, according to Dr. Phillips, are the Coconut Palm, *Ficus leucantotoma*, two other species of *Ficus*, *Macaranga tanarius*, and a long list of less favoured host-plants. Parts of the plant attacked are, in the coconut palm, the male and female flowers and the young nuts, leaves and young stems of other plants, and fruits of *Ficus* spp.

When the stem of *Macaranga* is deeply punctured by *Amblypelta*, a swollen, cracked canker is often produced, but sometimes there is a blackened, resinous patch in the pith, without any surface indication. Similar effects were observed on mango twigs. Leach made some very interesting observations on the effect of feeding by *Amblypelta* on the coconut palm. Within 24 hours of the insertion of the bug's proboscis, dissection of female flowers and young nuts showed large dark-brown patches. (See Plate 2). These dry up, and cause shrinkage, showing on the surface, underneath the bracts, as deep furrows. (See Plates 3 and 4). The bug usually penetrates the bracts to suck the soft, growing tissue below, or it may suck just at the distal edge of the bracts. It may suck quite large nuts, up to five or six months old, though after four months it is unlikely that the nut will fall. In the field, the nutfall caused by the bug is practically confined to female flowers and very young nuts.

When the bug sucks the harder, distal portion of the nut, only an inconspicuous surface lesion is caused, but when it sucks the basal, growing tissue of a nut which subsequently continues to grow, it leaves large, conspicuous cracks in the surface of the nut. (See Plate 5). Also it retards the growth of the nut on the side where the sucking has occurred, producing a characteristic asymmetrical shape. These characteristic lesions were observed in the field, and reproduced on a growing nut about 20 weeks old, on which Leach fed some caged bugs. (See Plate 6). As the nut grows larger, the lesions move further from the base. Usually they occur in a row, indicating more than one puncture. The knowledge that the bug causes these markings, a fact not mentioned by pre-war workers, proved of great importance in reconstructing the history of the bug-population of individual palms, and inferentially the history of the ant-population. For instance, if a palm is bearing well, but the mature nuts which have fallen to the ground are marked, it shows that *Amblypelta* has been present in the palm, but has been driven out by an invasion of *Oecophylla*. Similarly, if the nuts on the older spadices of a palm show markings, and those on the younger spadices are clean, it may be inferred that a light infestation by *Amblypelta* has been completely controlled. Moreover, the position of the markings on a growing nut shows approximately at what time the nut was punctured. The marks are originally made by punctures through, or at the edge of the calyx. As the nut grows, the lesions move further away from the calyx, so that the distance of the marks from the calyx is a measure of the time which has elapsed since puncturing occurred.

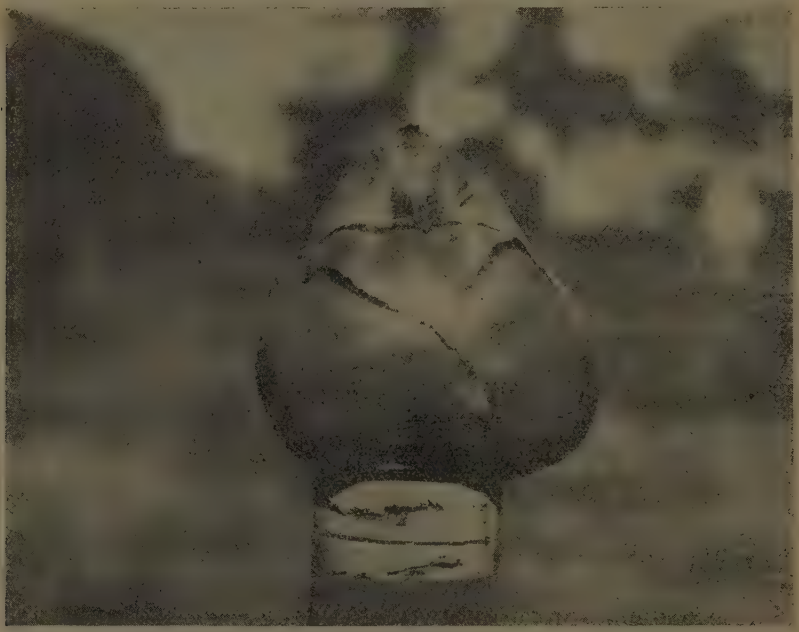


Plate 3 : Commonest nutfall stage : at or soon after pollination. Typical lesion extending beyond calyx.

—Photo R. Leach.

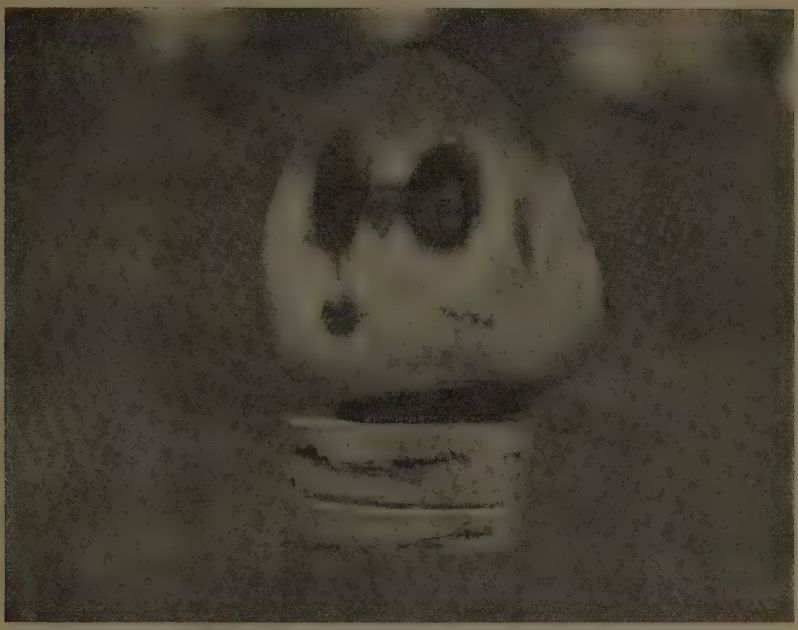


Plate 4 : Same nut as in Plate 3, with calyx removed.

—Photo R. Leach.

Another interesting effect on the female coconut flowers of feeding by the bug is that when the flowers are punctured before they have become receptive to pollen, they often do not fall to the ground, but remain on the spadix, where they dry up. In the course of time, the spadix falls to the ground with the undeveloped flowers still attached. In areas where this occurs, one may infer that the bug population is high. If a newly-opened spadix from such an area is examined, it will frequently be found that every female flower has been aborted by punctures, even though the spadix has been open for only a few days. In one area of about five acres at Kukum Plantation, where *Pheidole* was the dominant ant, 98 per cent of the palms were completely out of bearing, and a high percentage of spadices had large numbers of aborted flowers still attached. (For a more complete account of growth of a nut and the effects of feeding by *Amblypelta*, see Leach's discussion in Appendix A).

Before the war it was noted that in some nutfall areas there was a periodicity in the yield of the palms, a period of heavy nutfall being followed by a period of reasonable bearing. This was attributed to a fungus, which killed off the bugs when population was high, leading to their being crowded. Examples of this were noted on the Guadalcanal plantations.

Oecophylla smaragdina subnitida Emery.— This large, yellow ant is well-known to planters and agriculturalists throughout the B.S.I.P. It makes nests in trees, palms and shrubs by pulling together the leaves and webbing them with silk secreted by the larvæ, which are used as shuttles. Nests are often seen also in the spadices of the coconut palm, the nuts being webbed together. Preferrred trees for nesting are citrus trees and some species of *Ficus*. The workers forage for food, consisting of living and dead insects, including other species of ants, and the secretions of aphids, scale-insects and mealy-bugs, which are

Plate 5 : Typical scars due to feeding by *Amblypelta*. Old fallen nut on left, " green " nut on right. Latter attacked when young (scars near apex) and again five or six months later (scars near base).

—*Photo R. Leach.*

farmed by the ants. The workers are noted for their habit of moving in definite tracks, such as are provided by telephone wires and wire fences. During his survey of the plantations, Leach made detailed observations of the movements of *Oecophylla*, and found that they preferred to run along smooth surfaces, such as the midribs of fallen coconut fronds, and smooth vines with long internodes. Hairy vines such as *Passiflora* were avoided, though their runners were more attractive when dead. *Oecophylla* is an active and swift-moving ant, and very aggressive when disturbed.

Pheidole megacephala Fabr.—Pre-war workers referred to this ant as *Pheidole oceanica Mayr.*, but specimens collected by me on plantations in Guadalcanal, Malaita and the Russell Islands have been identified by Mr. J. Clark, the authority on Australasian ants, as *P. megacephala*. The only specimens of *P. oceanica* taken by the author were from isolated colonies in the Russell Islands. The question of the identity of the ant has been discussed in a preliminary note on nutfall in the Solomons.(8) *P. megacephala* appears to occur throughout the B.S.I.P., and is a small dark-brown ant, the soldiers being much bigger than the workers, with very large heads. Body length of workers is about 2·1 mms. and of soldiers 4·2 mms. A favoured nesting place of *Pheidole* in the plantations is among the aerial roots of the coconut palm, just underneath the projecting ledge of " bark " at the base of the trunk, which I have called the " apron." They also nest freely under fallen fronds and other debris which may be piled around the base of the palm, in fallen rotting spadices, nuts and fronds scattered over the plantation floor and in rotting wood

and coconut logs.* They build earthen-coloured runways of moist material, and these may frequently be seen around the base of the palm, the lower portion of the trunk, and running up the trunk beside large vines which grow up in neglected plantations. The runways are similar in appearance to those of termites. *Pheidole* preys on other insects, including other species of ants, and in Fiji is known to control house-fly breeding by carrying off eggs and larvæ from cattle droppings. It fosters mealy-bugs on the aerial roots of the coconut, and aphids on shrubs growing in the plantation undergrowth.

Iridomyrmex myrmecodiæ Emery.—The workers of this ant are about 2·5 mms. long, hairy, with a dark abdomen, bright yellow thorax and brown head. It is known to occur in the eastern portion of the Protectorate, on Santa Ana, the Three Sisters, San Cristoval, Malaita, Florida and Guadalcanal. Lever and Phillips both state that it has not been found on the Russell Islands or further west, though Wheeler[12] includes Ysabel in its distribution. Pre-war reports mention the occurrence of *Iridomyrmex* on Kukum plantation, Guadalcanal, but it was not seen by us on this plantation. During his survey of Lunga, Kukum and Tenaru plantations, Leach found *Iridomyrmex* in only one area at Tenaru. A possible explanation of its disappearance from Kukum is that large areas of this plantation were eliminated by bulldozing during the war. It is possible also the the continual air-spraying with oil solutions of DDT, which was carried out by U.S. Forces, may have affected this ant.

* Dr. Phillips, in a letter to Messrs. Lever Bros., has drawn attention to the fact that *Pheidole megacephala* also nests in the crown of the coconut palm. It is not known just how commonly this occurs, but in any case, the nests at the base of the palm are the important ones in the nutfall story.

Plate 6 : Scars formed by four adult *Amblypelta*, caged with medium-sized coconut on August 26. Note growth between August 26 and September 14.

—Photo R. Leach.

Plate 7 : Coconuts of different sizes on their side with calyx removed, showing tender, white base which is normally covered by the calyx, as in the upright nuts.

—*Photo R. Leach.*

Where *Iridomyrmex* is the dominant ant in plantations, as in the area at Tenaru, and on the Fairymead Sugar Co's. plantations on Malaita, it occurs in vast numbers. In the crown of the coconut palm it nests in spathes and under the fibrous material at the base of fronds. On the trunk nests are found under lichens and epiphytes, in depressions and cuts covered with "earthworks," i.e. earthen-coloured material which seems to consist mainly of vegetable matter—under dead " bark," among aerial roots, under fallen fronds, vines and debris resting against the trunk of the palm, and under the " apron." Nests are also found in and under fallen, rotting fronds and spathes, in dead branches of trees, and in epiphytic " ant plants " which grow on trees. At Baunani, Malaita, these ant plants were extremely numerous, being seen on trees growing in the neglected plantation, and on mango trees.

Iridomyrmex builds earthen-coloured runways, which may be up to two or three inches wide, up the trunks of palms and other trees, and when these are broken, they are seen to be crowded with countless workers. The runways branch out over the midribs of coconut fronds and the raches of spadices, leading to colonies of scales and mealy-bugs, which are fostered by the ant, and also kept under a cover of " earthworks." Other plants which supported the *Homoptera* fostered by *Iridomyrmex* are a *Pipturus* sp., *Sida rhombifolia*, *Macaranga tanarius* and a *Leguminous* tree. On the last-mentioned tree, scale insects, mealybugs and *Membracid* nymphs were fostered, on *Sida rhombifolia* scale insects were established on stems and twigs, all completely covered with " earthworks," and on *Macaranga* there were *Membracid* nymphs.

Mealybugs are fostered also on the aerial roots of the coconut palm. Throughout plantation areas occupied by this ant, the workers are found everywhere, and runways are found on and under fallen fronds, nuts and spathes. It is rarely that one sees another species of ant in *Iridomyrmex* territory. When disturbed, the workers swarm over one's body, biting and stinging fiercely.

Anoplolepis longipes Jerd.—This ant was only rarely met with, so is not discussed in this report.

Phillips([10]) states that, except for a few small colonies of indigenous ants, only the four species mentioned above are found on plantations in the B.S.I.P. This was certainly not the case at the time of our survey, as numerous "tramp" species were to be found nesting at the base of coconut palms. However, these do not appear to influence the balance of power among the above-mentioned species, or to have any effect on the incidence of *Amblypelta*.

OBSERVATIONS IN THE FIELD.

During our stay in the B.S.I.P., our headquarters were at Honiara, from which base we worked on Messrs. Lever Bros.' plantations of Kukum, Lunga and Tenaru. All of our time, except for a fortnight spent in the Russell Islands and Malaita, was occupied with work in this area, where the plantations had suffered very severely from premature nutfall before the war.

It was soon evident that the nutfall situation on these plantations had changed greatly during the war period. Many non-bearing areas had come back into production, coinciding with a much wider dispersal of the beneficial ant, *Oecophylla*. This conclusion was reached by comparing

Plate 8 : Growth of coconut fruits. Marked with pencil round edge of calyx on August, 5th, 12th, 19th and 26th. Nut on right shows five lesions produced by similar pricks of needle on August 12th.

—*Photo R. Leach.*

Plate 9 : Fallen coconut fronds leaned against palm trunk to provide a bridge over *Pheidole* stronghold at base of palm.

—*Photo R. Leach.*

pre-war reports with our own observations, by obtaining information from local planters, and by reconstructing the history of *Amblypelta* population on individual palms, using the method worked out by Leach of observing marked nuts. Many palms which were bearing exceptionally heavy crops of unmarked nuts had marked nuts among the old fallen ones around the base. Taking into account the evidence of the marked nuts, and the fact that the plantations were used by U.S. troops as camp-sites until about the end of 1945, it seemed likely that most of the recovery had taken place during the two or three years prior to our visit. At Tenaru, where we saw large areas of palms bearing extremely well, local observers were unanimous in stating that recovery had occurred only during the previous 12 months.

Why had *Oecophylla* been able to recover so much territory, when pre-war investigators had reported that it was steadily being driven out by the ant *Pheidole*? Before the war, Levers' plantations were kept very clean, cattle being grazed and all fallen fronds being burned. Thus the floor of the plantations was a clean mat, consisting largely of Japanese clover (*Desmodium sp.*). During the war a profuse undergrowth, comprising creeping vines, *Paspalum conjugatum, Mimosa pudica, Sida rhombifolia* and other plants had developed, as well as trees and shrubs. Cattle had been removed from the Guadalcanal plantations, and an intensive and prolonged programme of air-spraying with DDT solutions had been carried out by the U.S. forces as a malaria control measure. Thus the three main ways in which the pre-war situation had been varied appeared to be:—

(*a*) the presence of heavy undergrowth;

(*b*) the absence of cattle; and

(*c*) the spraying of the plantations with DDT.

(As to the details of this spraying, e.g. rate and frequency of application and areas treated, no definite information was obtained.) Another difference was that large areas of the plantations were cleared and bull-dozed during the war.

Having regard to these facts, and to the habits of *Oecophylla* and *Pheidole*, it seems likely that the free development of undergrowth and the leaving of fronds where they fell had favoured *Oecophylla*, and permitted it to recover ground. Leach made a thorough survey of Kukum, Lunga and Tenaru, and found that *Oecophylla* had made particularly good progress in areas where there were plenty of vines suitable for runways for the ant. In areas where the undergrowth consisted largely of *Paspalum dilatatum*, *Mimosa pudica* and the shrub *Triumfetta bartrami*, *Pheidole* still held considerable areas.

Thus it was possible to reconstruct the probable history of the decline and recovery of *Oecophylla* on these plantations. When the plantations were kept very clean, and all fallen fronds were picked up, *Oecophylla*, in descending or ascending the palms, would have to pass over the strongholds of *Pheidole* at the base of the palm, and would gradually be eliminated. This process was actually seen occurring, particularly on the plantations of Faielau and Pepesala, in the Russell Islands, where cattle had been concentrated during the war, and the floor of the plantations was consequently lawn-like. *Oecophylla* workers were assailed by numbers of *Pheidole* and dismembered. They also have a habit of pushing their heads into cracks in the " apron ", and are then seized by *Pheidole* waiting underneath, and pulled into the nests of the latter. Frequently large numbers of *Oecophylla*

Plate 10 : Undergrowth in heavy nutfall area, consisting of *Paspalum conjugatum* and *Mimosa pudica*.

—Photo R. Leach.

" *Plate* II : Undergrowth in area recovering from nutfall. Note vines growing over bases of palms.

—Photo R. Leach.

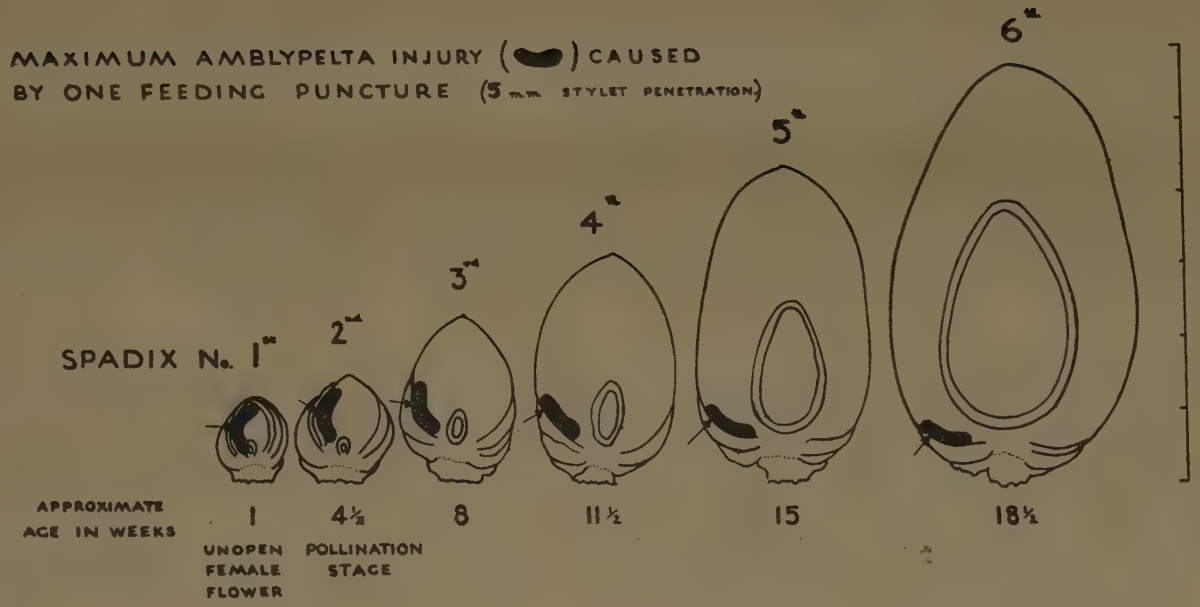
workers were seen milling around on the lower part of a palm trunk above the " apron ", obviously unable to go further down because of the presence of *Pheidole* below. At Pepesala, Leach rested a fallen frond against the trunk of such a palm, and within a few hours a line of *Oecophylla* workers was running down the frond to the ground. *Oecophylla*, of course, carries off *Pheidole* individuals also, but the strength of *Pheidole* lies in the strategic position of its nests athwart the path of *Oecophylla*, and in their protected situation under the " apron ".

When the plantations were neglected during the war, many fallen fronds lay at the base of the palms, and vines twined around the trunks and spread over the floor of the plantations. Thus *Oecophylla* was able to by-pass the nests of *Pheidole* by running along vines and fronds, and its progress into new areas was facilitated. It is now possible to understand the failure of pre-war attempts to establish *Oecophylla* in territory held by *Pheidole*. Nests of *Oecophylla* were placed in palms, which were then connected to adjacent palms by vines or twine, but apparently no provision was made for *Oecophylla* to by-pass the nests of its enemy when running up and down the trunks. It is worthy of record that we were told by planters of long standing in the B.S.I.P. that they thought that Levers' plantations suffered severely from nutfall because they were kept too clean.

The next step was to carry out experiments in the introduction of *Oecophylla* into nutfall areas held by *Pheidole*, making provision for the beneficial ant to by-pass the strongholds of its enemy. The technique employed was as follows:—

Nests of *Oecophylla* were cut off from the original tree—in this case either a citrus or a *Ficus* tree—and placed in wire-gauze cylinders with detachable lids. They were

FIG. 1



STAGES IN DEVELOPMENT OF COCONUT FRUIT

Figure 1 : *R. Leach del.*

then transported to a nutfall area, and either placed in the crown of a palm or tied to the trunk, several feet up from the ground, and wrapped around with coconut leaflets, as protection from sun and wind. When the nest had been placed in position, the lid of the cage was removed. In some cases, the native who took the nest to the crown of the palm emptied it out of the cage, and this method was apparently successful. The palm on which the liberation was made was connected with neighbouring palms by lines of fallen fronds laid on top of the undergrowth. At the base of the palms, the fronds were leaned against the trunk, several feet from the ground, the distal or leafy end being placed against the trunk, and the butt on the ground. (See Plate 9). The numerous leaflets touching the trunk thus gave *Oecophylla* the choice of a number of different paths, and minimized the danger that they would be assailed at one point by *Pheidole*, as might have been the case if the butt of the frond had been placed against the palm trunk. (Leach had noticed that there was a tendency for this to happen.)

Details of the experiments are as follows:—

Expt. 1—*Kukum, July* 31*st*, 1948.—One small *Oecophylla* nest was placed in the crown of a palm, and a large nest, in a wire-gauze cylinder, tied to the trunk, and wrapped around with coconut leaflets. This palm was then connected to several adjacent palms by lines of fallen fronds, and the various palms were interconnected. Heavy rain on the night of July 31st disturbed the ants in the large nest, and the following morning many queens, closely attended by workers, were seen taking shelter under the leaflets of a frond leaning against the trunk. Many larvæ and pupæ also had been carried from the nest, and numbers of dead workers, larvæ and pupæ were seen on the frond. In a runway of *Pheidole* situated under the outer bark, near the palm base, many dead *Oecophylla* workers and immature forms were stored. An inspection on August 10th showed that *Oecophylla* still existed on the palm, and workers were seen running along a line of fronds to a neighbouring palm.

Expt. 2—*Kukum, Aug.* 10*th*, 1948.—About 35 palms were connected up by lines of fallen fronds, and fronds were leaned against the trunks. One large nest of *Oecophylla* was placed in the crown of one palm, and three smaller nests, in a wire-gauze cylinder, were tied to the trunk of another palm. An inspection on August 11th showed that practically all the contents of the nest placed on the trunk had been removed to a young palm about six feet high, connected to the liberation palm by a line of fronds. On this young palm, a small nest, consisting of several leaflets bent over and webbed together, had been constructed during the 24 hours since the original nests were placed on the trunk. A few eggs and pupæ remained in the original nests, with a moderate number of living workers, and a considerable number of dead ones.

Expt. 3—*Lunga, Aug.* 11*th*, 1948.—This experiment was carried out in an area of complete nutfall, where the undergrowth was particularly unfavourable to the spread of *Oecophylla*, consisting of *Paspalum conjugatum*, *Mimosa pudica*, and a great deal of the shrub *Triumfetta bartrami*. Lines of fronds had frequently to be laid on top of the *Triumfetta* shrubs, which were about six feet high. One large nest of *Oecophylla* was placed in the crown of a palm, at the base of which was a strong colony of *Pheidole*, and this palm was then connected with eight neighbouring palms by lines of fronds. A large nest of *Oecophylla* was tied to the trunk of another palm in this area, and this palm was then connected to seven or eight neighbouring palms by lines of fronds.

Expt. 4—*Kukum, September* 13*th*, 1948.—This experiment was carried out in a complete nutfall area at Kukum, where *Pheidole* had been strongly entrenched. The large nest of *Oecophylla* which was used—it was broken, and considerable numbers of larvæ and pupæ were lost—was placed in the crown of one of nine palms which had been treated on August 23rd with a chlordane spray, with a consequent wiping out of *Pheidole* colonies at the base of the palms. Other lots of palms in the vicinity had also been given various treatments, and had few or no *Pheidole* at the base. The palm on which the nest was placed was connected with three other *Pheidole*-free palms and a

Ficus bush by lines of fronds. This experiment was carried out so that it might be checked at a later date, and results compared with those of liberations made in areas where *Pheidole* had not been eliminated. Vegetation in this area consisted of *Paspalum dilatatum*, *Mimosa pudica* and various vines. All debris and vegetation had been cleared around the bases of palms treated with insecticides, making a circle five to six feet in diameter, and it was observed that the tendrils of vines quickly invaded the cleared areas, and began to twine around the palm trunks.

Results of Expts. 1, 2 *and* 3.—The results of the experiments were checked by Leach on September 11th, and *Oecophylla* was found to be still present on one or more palms in each situation where it had been liberated. The periods which had elapsed since the date of introducing *Oecophylla* were:—

Expt. 1—42 days.
Expt. 2—32 days.
Expt. 3—31 days.

Phillips[10] states that the average interval between bursting of successive spadices in the B.S.I.P. is 23½ days, so sufficient time had elapsed even in the latest experiment for two new spadices to have burst and been attacked by *Amblypelta*, provided that the period between introduction of *Oecophylla* and bursting of the next spadix was not more than a few days. In each liberation area, the two youngest open spadices were cut from a palm on which *Oecophylla* appeared to be established, and only on one palm was the younger spadix not sufficiently open to have allowed access of *Amblypelta* to the female flowers. In experiment 3, where the nest had been placed on the crown of the palm, three palms were occupied by *Oecophylla*, and where the nest had been placed on the trunk, two palms were occupied.

In the figures presented below, " nutfall " includes female flowers or nuts which have fallen off, or which have remained on the spadix, but which have proved on dissection to be so damaged by *Amblypelta* as to be incapable of further development. The expression " marked " means that the nuts have been punctured by the bug, but the injury was superficial, and would not cause the nuts to fall.

Effect of Oecophylla Introductions on Nutfall:—

Expt.	*Nest placed on crown—* *Younger Spadix*	*Older Spadix.*	*Nest placed on trunk—* *Younger Spadix.*	*Older Spadix.*
1.	.....	.....	97 healthy (89%) 12 marked (11%) 0 nutfall (nil)	4 healthy (4%) 17 marked (17%) 81 nutfall (79%)
2.	85 healthy (93%) 6 marked (7%) 0 nutfall (nil)	55 healthy (68%) 4 marked (5%) 22 nutfall (27%)	Just opening	23 healthy (70%) 8 marked (24%) 2 nutfall (6%)
3.	42 healthy (98%) 1 marked (2%) 0 nutfall (nil)	35 healthy (100%) 0 marked (nil) 0 nutfall (nil)	36 healthy (100%) 0 marked (nil) 0 nutfall (nil)	12 healthy (48%) 1 marked (4%) 12 nutfall (48%)
	Total—Younger spadices		260 healthy (93%) 19 marked (7%) 0 nutfall (nil)	
	Total—Older spadices		129 healthy (47%) 30 marked (11%) 117 nutfall (42%)	

Controls showed practically complete nutfall.

Thus it was evident that *Oecophylla* had held its own for periods up to six weeks, when introduced into nutfall areas held by *Pheidole*, and almost immediately after its introduction had begun to exert remarkable control of *Amblypelta*. The figures for the younger spadices show that by the time they burst control of the bug was practically complete. It now remained to be seen whether the introduced colonies would increase in numbers and in area of distribution.* There was good reason to hope that similar introductions of *Oecophylla* into nutfall areas occupied by *Pheidole* would prove a satisfactory solution of the problem.

In the early stages of the programme, it would probably be necessary to use lines of fronds, and it is considered vital that a path should be provided by which *Oecophylla* can by-pass *Pheidole* nests on its upward and downward journeys. It would be assisted in its movement through the plantation, and from the palm trunks to the ground by the establishment of creeping cover-crops, such as *Centrosema pubescens* or *Pueraria javanica*. When both *Oecophylla* and the cover-crop are firmly established, it is considered that the beneficial ant would remain in strength throughout the plantation, and that *Amblypelta* would be permanently controlled.

Observations in the Russell Islands.—During a short visit to the Russell Islands, some observations were made on the distribution of *Oecophylla* and *Pheidole*. Though neither *Amblypelta* nor premature nutfall has been recorded in this group of islands, the ant situation is of great interest.

The plantations of Pepesala and Faielau had for several years prior to our visit been heavily overstocked with cattle. On these plantations, despite the facts that (*a*) the floor of the plantations was lawn-like, and (*b*) *Pheidole* was present, *Oecophylla* was the dominant ant, occupying large areas of the plantations, while *Pheidole* was confined to comparatively small areas. The lawn on the plantation floor consisted at Faielau mainly of *Paspalum conjugatum* and *Chrysopogon aciculatus*, with other small plants and some shrubs (including *Ficus spp.*) and trees, and at Pepesala of *P. conjugatum, C. aciculatus, Desmodium sp.*, (the so-called Japanese clover) scattered patches of *Mimosa pudica* and numerous *Ficus* shrubs.

At Faielau, *Pheidole* occupied a roughly circular area of perhaps 70 acres, extending north-west from the wharf. Leach pointed out that in this area all the fronds and fallen nuts had been gathered into lines running down the middle of the rows of palms, whereas the remainder of the plantation had not been so treated. The piling of the nuts and fronds had been done about six months before our visit. Where the fronds had been allowed to lie where they fell, there were usually some lying against the butt of the palms in such a way as to provide a bridge for *Oecophylla*. At Pepesala, *Pheidole* occupied an area about ten chains in diameter near the wharf, and in another area, about 300-400 yards in diameter, there were *Pheidole* palms, *Oecophylla* palms, and palms on which both species were present, and evidently a struggle for supremacy was going on.

It was unfortunate that we had no precise information as to the status of *Pheidole* in the Russell Islands before the war. Lever, in the *B.S.I.P. Agricultural Gazette*(4) stated that *Pheidole* appeared to be present throughout the B.S.I.P., and Phillips and Cottrell-Dormer, in reports on the files of Lever Bros., made indirect references to its presence on the plantations of Pepesala and Banika, in the Russell Islands. However, as premature nutfall does not occur in the Russell Islands, owing to the apparent absence of *Amblypelta*, detailed studies of the ants there were not made by pre-war workers, though *Oecophylla* was known to be strongly established. Hence we did not

* The author visited the Solomon Islands again in May, 1950, and found that almost the whole of the plantations of Kukum, Lunga and Tenaru were occupied by *Oecophylla*. The bad nutfall areas where introductions of the beneficial ant had been made were in full bearing, and *Pheidole* was not seen. This inspection was made at too late a date to indicate whether the change had been due to our introductions or to a general spread of *Oecophylla* throughout the area. It was noted, however, that many more vines were present in the areas which had previously been occupied by *Pheidole*. As most of the palms had produced mature nuts, recovery must have occurred within about nine months of our original survey.

know whether *Pheidole* had advanced or retreated in this area during the period of the war. At the time of our visit it was present on all the plantations inspected, namely Pepesala, Faielau (both kept clean by heavy stocking with cattle), Lingatu, Banika and Ufa (all overgrown, because of the absence of cattle). In all of these plantations, except Ufa, where *Pheidole* appeared to be the dominant ant, *Oecophylla* was very strongly established. There appeared to be little doubt that *Pheidole* was present on all these plantations before the war. The plantations were kept very clean, like those on Guadalcanal, yet as far as we can gather, without having concrete survey data on which to work, *Oecophylla* was the dominant ant, and still is, except at Ufa. Hence two important questions arise. (i) Why was not *Oecophylla* driven out of large areas by *Pheidole* before the war? and (ii) Why had *Oecophylla* retained its supremacy on the clean plantations, Pepesala and Faielau, during the war years?

A factor which may enter into the answer to question (i) is that the Russell Islands plantations are considerably younger than those on Guadalcanal, and hence the driving out of *Oecophylla* may not have reached such an advanced stage. Also, *Pheidole* may have been introduced to the Russell Islands at a date later than that of its introduction to Guadalcanal. As *Amblypelta* is not present, there would be no premature nutfall to attract attention to the spread of *Pheidole*. As to question (ii), conditions at Pepesala and Faielau differed from those existing before the war inasmuch as (*a*) fallen fronds had been left where they fell, (except in a small area at Faielau where *Pheidole* was dominant) and (*b*) many *Ficus* bushes had grown up, especially at Pepesala, and these were freely used by *Oecophylla* for nesting. These two factors were favourable to *Oecophylla*.

The future movements of *Oecophylla* and *Pheidole* on the plantations will be interesting and important. Leach has mapped out the distribution of these two species and of *Iridomyrmex* on Kukum, Lunga and Tenaru, on Guadalcanal, and of *Oecophylla* and *Pheidole* on Faielau, in the Russells, and we also have some knowledge of the distribution of the two latter species on Ufa, Lingatu and Pepesala, so that future investigators should be able to follow the movements of the species.

SITUATION IN *IRIDOMYRMEX* AREAS.

The situation where the ant *Iridomyrmex myrmecodiæ* Emery was dominant was more difficult from the point of view of controlling premature nutfall. Though this ant was seen on an isolated group of three young palms, and on an isolated shrub at Honiara, we had been some weeks on Guadalcanal before Leach's plantation surveys revealed its presence in a comparatively small area on Tenaru. Pre-war workers had reported it on Kukum, but we did not find it on this plantation. We have no definite theory as to why it should have disappeared from Kukum, though the bulldozing of large areas of the plantation may have eliminated it. Continued air spraying with DDT solutions by the U.S. forces may also have had some effect. On the Fairymead Sugar Company's plantations on Malaita, according to Europeans and natives who knew the situation before the war, *Iridomyrmex* had extended its range during the war years. Certainly it seemed to occupy the bulk of the area inspected at Baunani plantation, Malaita, where only a narrow strip along the beach was in possession of *Oecophylla*.

Because *Iridomyrmex* nests in great numbers in the crown of the palm, as well as in cuts and depressions in the trunk, and under the "apron", the prospects of establishing *Oecophylla* in an *Iridomyrmex* area, without prior elimination of the latter ant, seem poor.* Hence it is thought that, where this ant is dominant in a plantation effected by premature nutfall, the immediate control measure indicated is a direct attack on *Amblypelta* by the introduction of parasites or the use of insecticides.†

* On a Malaita plantation where there had been a luxuriant growth of the creeping cover crop, *Pueraria sp.* since before the war, *Iridomyrmex* was dominant, though *Oecophylla* existed on a few palms.

† An attempt is in progress to establish the *Tachinid*, *Trichopoda pennipes F.*, of which a strong colony was liberated at Baunani Plantation, Malaita, during May, 1950.

An observation of some interest made on Manaba and Baunani plantations, in Malaita, was that on almost every palm examined which was occupied by *Oecophylla*, *Pheidole* was found nesting at the base. At Manaba, an excellent cover-crop of *Pueraria* is established, and *Oecophylla* uses this vine for ascending and descending, thus by-passing the *Pheidole* nests. At Baunani, fallen fronds and various species of vine were used by *Oecophylla*. Thus it may be that *Oecophylla* is not capable of successfully invading *Iridomyrmex* territory, but where *Pheidole* prevents *Iridomyrmex* from occupying a palm, *Oecophylla* is able to survive. At Baunani there were a few isolated bearing palms, with *Oecophylla*, in the middle of an *Iridomyrmex* nutfall area. Mr. Bergen, manager of the Fairymead Sugar Company's estates, stated that these few palms had always borne well. *Pheidole* was seen at the base of the palms, which were connected to neighbouring citrus and *Ficus* trees by a mass of creepers. It will be recalled that these species of trees are much favoured by *Oecophylla* for nesting and farming *Coccids*.

Regarding the effect of *Iridomyrmex* on premature nutfall, the palms in the area occupied by this ant at Tenaru had varying yields, from poor to good, with many marked nuts, indicating the presence of *Amblypelta*. At Baunani and Manaba also, some trees occupied by *Iridomyrmex* had good yields, but a very large area of Baunani showed practically complete nutfall. At Tenaru, a high-yielding *Oecophylla* area adjoins the *Iridomyrmex* area, so it seems possible that the bug-population in the area has been kept low by *Oecophylla*, explaining the comparatively good yield of the *Iridomyrmex* palms. Some at least of the good *Iridomyrmex* palms on Malaita were also adjacent to *Oecophylla* palms. It is of interest that two palms at Baunani occupied by *Pheidole* were yielding well, but these also were next to *Oecophylla* palms.

CONTROL OF ANTS BY INSECTICIDES.

A long series of field trials of insecticides to control *Pheidole* and *Iridomyrmex* was conducted. Methods tested were: (1) Baiting; (2) Sticky bands and (3) Spraying and dusting.

(1) *Baiting*.—Two types of baits were tried against *Pheidole* and *Iridomyrmex*, namely a grease bait consisting of beef dripping and arsenite of soda, and a sweet bait, in which golden syrup had to be used instead of honey, which was unobtainable in Honiara. The baits were placed in 2 oz. tobacco tins, into which a cylinder of 16-mesh wire gauze was inserted, the lid then being placed on top of the cylinder. This left an opening about quarter inch deep between the lid and the top of the tin, so that *Iridomyrmex* and *Pheidole* workers could pass through the gauze, but not *Oecophylla* workers. As neither bait seemed to be attractive to either of the species, baiting was not persevered with.

(2) *Sticky bands*.—Commercial banding material was not available, and no really satisfactory band was made. When castor oil and resin were used, the band was sufficiently sticky to prevent the passage of ants, but ran excessively, and dried out within a fortnight. When petroleum jelly was added to the mixture, it did not run so badly, but ants were able to pass over it. Chlordane, Gammexane and DDT were tried as ingredients in the bands, but no satisfactory results were obtained.

(3) *Spraying and Dusting*.—(*a*) Dusting of the plantation floor and bases of palms with DDT (2 % p-p'isomer) and Gammexane (0·5 % gamma isomer) was ineffective against both *Pheidole* and *Iridomyrmex*.

(*b*) Spraying of bases of palms with a suspension of Gammexane Dispersible Powder was ineffective against the ants.

(*c*) Spraying of the bases of palms with Chlordane emulsion (one part of 74 % emulsifiable concentrate in 200 parts of water) was very effective in killing both *Pheidole* and *Iridomyrmex*. Against *Pheidole*, the base of the palm was sprayed to about one foot above the ground, and results were greatly improved by previously cutting away the "apron", to expose the nests beneath. Against *Iridomyrmex*, six feet of the basal part of the trunk was sprayed, all loose "bark" and covered runways being knocked off before spraying. Spraying was done in all cases with a knapsack sprayer, using rather

a coarse jet, and all cracks and crevices were thoroughly treated. About one pint per palm was used against *Pheidole*, and about two pints against *Iridomyrmex*.

All ants hit by the spray were killed, as were those which passed over the sprayed area within five or six days after treatment, though there were many heavy falls of rain during the period. For several weeks after spraying, no ants were seen on the palm trunks. However, three weeks after spraying palms occupied by *Iridomyrmex*, it was found that countless numbers still remained in the crowns of the treated palms.

(*d*) Spraying the bases of palms with technical DDT dissolved in diesoline was also very successful against both species of ants.

The spraying of the palm bases was undertaken with the idea that if the harmful species of ants could be thus controlled, it might be possible to colonize *Oecophylla* in the treated areas later. However, in the case of areas occupied by *Pheidole*, the beneficial ant is able to re-occupy the areas without preliminary spraying, provided that it has the help of vines and fallen fronds. In the case of *Iridomyrmex*, treatment of the whole palm would be necessary. In the event that attempts to control *Amblypelta* by biological means are unsuccessful, power-dusting of affected areas with an insecticide which would kill both ants and bugs, followed by introductions of *Oecophylla*, would be worth considering.

ANT POPULATION OF COCONUT PLANTATIONS.

During the course of the investigation, many collections of ants from coconut plantations were sent to Australia for identification. These were identified by Mr. J. Clark, to whom they were forwarded by courtesy of Mr. T. Greaves, Research Officer, Division of Entomology, C.S.I.R.O., Canberra. A list of the species is presented in Appendix B. The species which were most numerous and widely distributed on the plantations on Guadalcanal where most of our work was done were: (excluding *Pheidole, Iridomyrmex* and *Oecophylla*, and in approximate order of incidence): *Paratrechina vaga, Cardiocondyla nuda atalanta, Paratrechina atomus, Pheidole umbonata, Monomorium fraterculus, Tapinoma melanocephalum, Paratrechina vividula* and *Camponotus ? chlorotica.*

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APPENDIX A

EXTRACT FROM REPORT TO LEVER BROS. BY R. LEACH

STAGES IN THE DEVELOPMENT OF A COCONUT FRUIT

In order to appreciate the effect of *Amblypelta* injury it is necessary to know how a young coconut develops. The husk (pericarp) is softest where it is colourless under the persistent perianth segments (3 + 3) usually termed the " calyx " at the base of the nut. (See Plate 7). As the seed grows and increases considerably in size, with the endosperm providing the " meat " of the mature coconut, the only cells of the young husk which elongate appreciably are those situated in the tender colourless portion*. This is clearly demonstrated by drawing a line with a wax pencil on the surface of the young nut along the top edge of the calyx at regular weekly intervals, a series of such lines being thus obtained which remain practically equidistant from each other throughout the development of the nut (See Plate 8).

The importance of this feature of nut growth lies in the fact that once a nut has suffered any superficial injury early in its development, that injury always remains at approximately the same distance from the apex of the nut as when it was originally formed. Although the husk soon stops elongating, it is continually increasing in diameter, so that an injury near the surface of a young nut may become distended to form an open wound. (Plate 8 was taken on September 14th and shows the lines drawn on August 12th, 19th and 26th. On August 12th a series of similar sized lesions were made by pricking the husk, to a depth of about $\frac{1}{8}$ inch, with a needle at different places along the surface of the nut. The lowest lesion was made through the calyx into the white, tender base of the young nut and as elongation was only active in this region, this was the only one which resulted in the formation of a gaping wound later).

By measuring the size of a nut and by knowing its growth rate, the approximate date upon which any such injury occurred can therefore be calculated. A good average figure for growth of a nut in length is about 1·5 mm. per day.

INJURY CAUSED TO COCONUTS BY *AMBLYPELTA*.

(*a*) *Method of feeding.*—Experiments and observations have shown that *Amblypelta* can suck nuts of all sizes. In captivity this insect has been seen feeding in one position for 40 minutes without withdrawing its stylets (See Plate 1). They often move deeper into the tissues after sucking for some time nearer the surface of the nut. The insect is so intent on feeding that it is quite easy to decapitate it with a snip of the scissors. By using this method and subsequently cutting sections of the nuts, the stylets have been seen penetrating the nut to a depth of 4·35 mm. From measurements of the proboscis, the limit of penetration would appear to be about 5 mm. for an adult *Amblypelta* bug.

(*b*) *Nature of injury.*—The saliva of *Amblypelta* is apparently extremely toxic and oxidation of the tissues is rapid in the water-soaked sucked area soon after feeding has ceased. Within 24 hours this area has turned chocolate brown, frequently with a lighter coloured centre that subsequently collapses to form a watery, hollow lesion†.

The actual area of the nut affected by any one feed depends upon the length of time that the insect sucks, and by the state of maturity of the tissues concerned. The maximum extent of the injury made at the time of sucking covers an area approximately two-thirds of an inch long by one

* The actual process appears to be that the fibres of the vascular strands elongate and the parenchymatous cells of the ground tissue are pulled apart in the process. Although elongation practically ceases beyond the limits of the calyx, the nuts are continually widening and the fibrous vascular strands are gradually stretched apart in the mesocarp, forming the coconut fibre of commerce.

† When feeding in the tender pith of young stems of *Macaranga tanarius*, a common indigenous host plant, the parenchyma cells are rapidly disintegrated by the saliva and the space thus formed is filled with resin which subsequently turns into a solid brown or black mass in the pith. By splitting branches of this small tree it is therefore possible to see evidence of previous *Amblypelta* injury in the pith even in the absence of any superficial canker.

sixth of an inch deep and broad. Such an area affects a considerable part of the youngest nut and only one puncture is sufficient to kill the ovary of an unpoened female flower. (Fig. 1 represents the effect of similar sized injuries in nuts of different sizes; nuts were cut in half and imprinted on paper in order to obtain the exact proportion and position of husk and calyx. The following points of interest are worthy of note in the diagram:—

(i) The unopened female flower, i.e. before pollination.

(ii) The position of the calyx segments at the junction with the flower stalk.

(iii) The increasing diameter of the nuts above the upper edge of the calyx.

(iv) Taking 5 mm. as the maximum depth to which the stylets of *Amblypelta* can penetrate, an arrow marks the lowest position which can be reached by the stylets).

One can readily appreciate how sucking of the youngest nuts, up to 4½ weeks old, causes injury so close to their point of attachment to the stalk that nutfall is inevitable when nuts of that size are sucked by *Amblypelta*. The devastating effect on the ovaries of the unopened flowers is obvious (See Plate 2); they never develop any further, but shrivel in the calyx and may remain there until the spadix and spathes fall to the ground a year later. Palms affected in this severe manner are therefore seen to have spadices of all ages with many of the unopened female flowers still attached.

Nuts frequently fall when sucked during or soon after the pollination stage. The lesions are then often visible just beyond the calyx, and if the latter is removed the lesions appear as dark chocolate brown, shrunken areas (See Plates 3 and 4).

When more than four and a half weeks old, the affected lesions are not so close to the base and the tissue is slightly more mature, i.e. the vascular strands are more lignified (See Table I).

Cottrell-Dormer and Phillips stated that 90 per cent of the nuts fell before they were six weeks old (not exceeding 2″ in length with calyx removed) and the larger the insect population the smaller is the average size of the fallen nut. Nuts up to 12 weeks old may fall as a result of *Amblypelta* injury. The larger the nut, the greater number of lesions seem to be required to cause this, and the older nuts can withstand much injury without falling. If the feeding tends to be unilateral, the nut may become contorted in its subsequent growth.

TABLE I.

NUT DEVELOPMENT.

Age (weeks)	Length without calyx	Distance from lesion to centre of stalk (A)	Circumference of nut at A	Average number vascular strands with lignified vessels
	(in.)	(mm.)	(mm.)	*
1	1	..	..	0·0
4½	1¼	7	21·9	1·0
8	2	12	44·0	3·5
11½	3	12	50·2	5·0
15	4	12	56·5	9·0
18½	5¼	12	69·1	12·0

* Transverse sections of the husk 1·5 mm. wide, cut at the base of the lesion.

Once a nut has reached the age of eight to 12 weeks, it usually does not fall as a result of *Amblypelta* injury. Injuries in the tender portion of the husk under the calyx, where tissues elongate, result in characteristic black scars being formed on the surface of the nuts during their subsequent development. These scars may be clearly visible on tall palms even with the naked eye. They usually exude considerable quantities of gum. Plate 6 was taken on September 14th and shows the scars formed on a half-grown nut resulting from *Amblypelta* injuries received shortly after August 26th. Plate 5 shows older scars on mature nuts. When the scars are situated at one level round the circumference of a nut it is an indication that the insect was feeding on that nut only over a short period of time (See Plate 5).

When *Amblypelta* sucks into the more mature parts of the "green" husk, the affected areas may remain hidden by the healthy skin (exocarp) and may only be noticed by the presence of either small lumps or sunken, wrinkled areas under the unbroken skin.

These characteristic scars supply extremely reliable and positive evidence that *Amblypelta* was present during the growth of any scarred nut.

APPENDIX B.

SPECIES OF ANTS FOUND IN COCONUT PLANTATIONS.

Species	Guadalcanal	Russell Is.	Malaita
Odontomachus hæmatoda Latr.	X	....	....
Ponera pruinosa Emery	X	X	X
Pheidole oceanica Mayr.	....	X	....
Pheidole megacephala Fabr.	X	X	X
*Pheidole philemon Forel	....	X (jungle)	....
Pheidole umbonata Mayr.	X	X	X
*Pheidole (Pheidolacanthinus) belli Mann.	....	X (jungle)	....
Pheidole ,, sexspinosa Mayr.	X	....	....
Pheidole ,, fuscescens Emery	X	....	....
Monomorium pharaonis Linn.	X (house)	....	....
,, (Lampromyrmex) fraterculus Sants	X	....	....
,, sp.	....	X (jungle)	....
,, sp.	X	....	....
Tetramorium guineense Fabr.	X	....	....
,, tonganum Mayr	....	X (jungle)	....
*Oligomyrmex viehmeyeri Mann	X	....	....
Strumigenys godeffroyi Mayr	X	....	....
Cardiocondyla nuda atalanta Forel	X	....	....
? Pristomyrmex sp.	X	....	....
Iridomyrmex myrmecodiæ Emery	X	....	X
Technomyrmex albipes Smith	X	....	....
Tapinoma melanocephalum Fabr	X	....	....
Anoplolepis longipes Jerd.	X	....	X
Paratrechina (Paratrechina) longicornis Latr.	X	X	....
Paratrechina (Nylanderia) vaga Forel	X	X	X
Paratrechina ,, vividula Nyl.	X	X	....
Paratrechina ,, minutula Forel	X	X	....
Paratrechina ,, atomus Forel	X	X	X
Oecophylla smaragdina subnitida Emery	X	X	X
*Camponotus (Myrmoturba) santæ crucis Mann	X	X	....
Camponotus (Colobopsis) belli Mann	X	....	....
Camponotus (Myrmophyma) ? chlorotica Em.	X	....	....
Camponotus (Myrmamblys) reticulatus bedoti Forel	X	....	....
*Polyrachis (Myrma) salomo Forel	....	....	X
Polyrachis (Chariomyrma) guerini Latr.	X	....	....

NOTE.—Where the distribution if qualified by a word in brackets, e.g. " (jungle) ", the species was not found in a plantation.

It will be realized that this list is by no means exhaustive. While collecting on the Guadalcanal plantations was fairly thorough, it was by no means so in the Russell Islands and Malaita.

*Indigenous species.

BIOLOGICAL CONTROL OF INSECTS AND PLANTS IN FIJI

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(PAPER READ AT THE 7TH PACIFIC SCIENCE CONGRESS, 1949.)

INTRODUCTION.

Biological control of insects and weeds has been singularly successful in the Fiji Islands, where the amount of work done along these lines has been considerable, having regard to the size and the resources of the group. The reasons which may be assigned for the success achieved are as follows:—

(*a*) the restricted nature of the island fauna, which offers little competition to introduced species, compared with that which they would encounter in continental areas;

(*b*) the favourable climate, which permits of growth and reproduction throughout the year;

(*c*) the concentration, by a team of efficient workers, on biological control of the insect pests of a single crop, the coconut palm;

(*d*) the comparatively large expenditure, by a small community, which made the work possible.

In passing, it may be remarked that the method of biological control is particularly valuable as a weapon against insect pests of the coconut palm in the South Pacific islands, quite apart from the fact that ecological conditions are well suited to its practice. In normal times, coconuts are a crop of low value per acre, and the cost of spraying or dusting them is heavy, as the work would call for power machines or aeroplanes. Moreover, many of the island peoples, such as the Melanesians of Papua, New Guinea, and the Solomon Islands, are very backward, and not in a position to finance or efficiently implement artificial control measures. Hence a greater concentration on biological means of control is justified than would be the case in more advanced countries.

In this paper it is proposed to present a short history of biological control work in Fiji, and then to deal in greater detail with the more outstanding campaigns, and to comment on points of particular interest.

HISTORY.

In 1911 the Government Entomologist, Mr. Frank P. Jepson, introduced from Hawaii the Lantana Seed Fly, *Agromyza lantanæ* Frogg., which rapidly became established on Lantana camara in Fiji.[5] In 1912 the Colonial Sugar Refining Company sent Mr. D. S. North to Hawaii to import colonies of the Tachinid *Microceromasia sphenophori*, Vill., a parasite of the weevil borer of sugar cane, *Rhabdoscelus obscurus* Boisd. Further introductions of this parasite from Hawaii were made in 1913 by Professor J. F. Illingworth[3] of Honolulu, and in 1917 by Mr. R. Veitch, of the Colonial Sugar Refining Company.[34] Breeding and distribution of the insect was carried on by the Company for years. The parasite was then found to be established in the field, but has not been a spectacular success. Its effect on the incidence of the weevil has never been thoroughly evaluated, though Veitch[34] considered that the parasite had been responsible for a reduction in damage by the weevil in the Nausori area.

In 1913 Jepson went to Java in search of natural enemies of the Banana Weevil Borer, *Cosmopolites sordidus*, Germ.,[4] and decided to import the Histerid predator, *Plæsius javanus*, Er., which has since become known in Fiji as " Jepson's Beetle." As the beetles would survive for several months without food, if kept in moist soil, no great difficulty was experienced in exporting them to Fiji. Several thousand were liberated, and began to reproduce in the field, larvæ and pupæ being found several months later. Nothing was then seen of the predator for several years. In 1918 a

further supply of 163 beetles arrived from Java by post, packed in sphagnum moss. In 1921 *P. javanus* was recovered in the field,[18] and subsequently it became well established on the island of Viti Levu.

In 1917, Mr. R. Veitch, of the Colonial Sugar Refining Company, introduced the the Scoliid wasp, *Scolia manilæ* Ashm., as a parasite of whitegrubs attacking sugarcane. Five years later this wasp was found to be established in the field.[35]

In 1920 and 1921, Mr. H. W. Simmonds, Government Entomologist, travelled to Tahiti to obtain parasites of the scale insect *Aspidiotus destructor* Sign., and brought back *Aphytis chrysomphali*, Mercet and *Aspidiotiphagus citrinus* Craw.[16] and [17]. In 1922 and 1923, Simmonds introduced from Hawaii the butterflies *Thecla echion*, L., and *Thecla bazochii* God., parasites of *Lantana camara*.[19]

The first spectacular success of biological control in Fiji was the suppression of the Levuana Moth, *Levuana iridescens* B-B., by the Tachinid parasite *Ptychomyia remota*, Ald.[33] This Zygænid moth was threatening the existence of the coconut industry, and in 1924 a committee was formed to organize action against the pest. Known as the Levuana Committee, and later as the Coconut Committee, it included the Superintendent of Agriculture as Chairman, and Sir J. M. Hedstrom and Mr. E Duncan as members. The Committee employed Mr. A. M. Lea to investigate parasites of the moth in Malaya, and shortly afterwards Dr. J. D. Tothill and Messrs. T. H. C. Taylor and R. W. Paine were appointed to the staff. As a result of the work of these three entomologists, assisted by Mr. H. W. Simmonds, complete control of *Levuana iridescens* was accomplished by 1928.

Meanwhile, in 1924, Lea had introduced several species of ladybird beetles, including *Cryptolæmus montrouzieri* Muls., and the lacewing *Chrysopa ramburi*, Schreider, from Australia.[24] Messrs. Paine and Taylor brought from Hawaii in 1925, a number of species of parasitic *Hymenoptera*.[33]

In 1927 and 1928 Taylor and Paine worked on the control of *Aspidiotus destructor*, a serious pest of the coconut palm. Paine studied the pest and its parasites in Fiji, while Taylor went to Java and Trinidad in search of natural enemies.[31] From Java he imported four species of internal parasites and two predators, *Scymnus sp.* and *Aleurodothrips fasciapennis*, Frankl. From Trinidad were brought five species of *Coccinellids*, and one of these, *Cryptognatha nodiceps*. Mshl,, registered another overwhelming success, so that 18 months after its introduction, *Aspidiotus destructor* was very hard to find.

In 1928, Simmonds visited Hawaii and brought back the bug *Teleonemia scrupulosa* Stal., a parasite of *Lantana camara*, and various other parasitic and predatory insects.[20] The bug quickly established itself in the field, and has since exercised some degree of control on Lantana, though checked by the attacks of the Lygæid *Germalus pacificus* Kirk., and by heavy rainfall[2] and [21]. In 1929, Simmonds imported a colony of the dung-beetle *Copris incertus* var. *prociduus* Say.,[22] which has since become very well established.

In 1929, Paine went to Java to investigate the possibility of introducing parasites of the Coconut Spike Moth, *Tirathaba trichogramma* Meyr., and Simmonds travelled to Trinidad to bring back colonies of *Liothrips urichi*, Karny, for the control of the weed *Clidemia hirta*. Its introduction to Fiji had been recommended by Taylor, who had studied its biology while in Trinidad in 1927–28.[28] The introduction of the thrips in 1930 proved an outstanding success, and the weed is no longer troublesome in Fiji.[25] Paine's investigations in Java, covering a period of 18 months, were most skilfully conducted, but unfortunately have never been published in full. The only published reference to this work is contained in a Bulletin of the Department of Agriculture, Fiji.[15] In 1930, Taylor, who had made a detailed study of *T. trichogramma* in Fiji,[29] brought back the parasite *Apanteles tirathabæ* Wilk., which rapidly established itself in the field. Paine continued his studies in Java, and in 1931 returned to Fiji with colonies of an egg parasite, *Telenomus tirathabæ*, Ferr., and a Tachinid, *Erycia basifulva*, Bezzi. In 1933 he proceeded once more to Java, and brought back

colonies of *Erycia basifulva* and another parasite, *Nemeritis palmaris* Wilk. All these parasitic species became established in the field.[15] During the course of this work, Paine also introduced the predatory mosquitoes *Megarhinus splendens*, Wied., from Java and *M. inornatus*, Walk., from Rabaul.[14]

While in Java, Paine had made a preliminary study of the parasites of the leaf-miner *Promecotheca nuciferæ*, Maulik, as an allied species, *P. reichei*, Baly, was a severe pest of the coconut palm in the Lau group of islands in Fiji. In 1931, Taylor proceeded to Java to carry on the investigation, and the result of his work was the introduction to Fiji of the Eulophid *Pleurotropis parvulus*, Ferr., in 1933. Another remarkable success resulted, complete control of the pest being brought about with great rapidity. This campaign is fully dealt with in Taylor's excellent treatise on the subject.[32] At the same time, Taylor introduced a species of *Cremastus*, a parthenogenetic parasite of the banana Scab Moth, *Nacoleia octasema*, Meyr.[30]

In 1935, Simmonds introduced two species of Fruit Fly parasites from Hawaii, *Tetrastichus giffardianus*, Silv., which quickly became established in the field, and *Opius humilis*, Silv., of which only one small colony was released.[27] In the same year, a strong colony of *Cremastus flavoorbitalis* Cam., a parasite of Pyralids, was introduced from Hawaii and released.[26] According to information supplied by the Colonial Sugar Refining Company, three species of beneficial insects were introduced by their staff from Hawaii during 1936. These were *Anagyrus saccharicola*, Timb., a parasite of the sugar-cane mealybug, *Trionymus sacchari*, Ckll., and two enemies of the weed *Cyperus rotundus*, L. namely the moth *Bactra truculenta*, Meyr., and the weevil *Athesapeuta cyperi*, Marsh. Further fruit-fly parasites introduced were *Dirhinus giffardii* Silv. from India in 1937[6] and [13] and *Melittobia indicum* Silv. from New South Wales in 1938.[7] In 1938 also, a large consignment of the Histerid *Pachylister chinensis*, Quens., was sent from Java by Simmonds for housefly control.[8] In 1941, R. A. Lever, who succeeded Simmonds as Government Entomologist in 1938, introduced *Microphanurus basalis*, Woll., an egg-parasite of *Nezara viridula*, L.,[10] and in 1943 *Diadromus collaris* Grav., a parasite of *Plutella maculipennis*, Curt., was imported from New Zealand.[11]

A list of the parasites and predators imported into Fiji is presented as an Appendix. This list is based on those compiled by Simmonds[24] and Lever.[9]

NOTABLE CAMPAIGNS.

(A) *Levuana iridescens*, B-B.

It is proposed to describe some of the more outstanding work done in the field of biological control in Fiji, and the first campaign to be considered is that against the Levuana Moth, *Levuana iridescens*, B-B. This account is taken from "The Coconut Moth in Fiji," by Tothill, Taylor and Paine.

The first definite record of the occurrence of the pest was made in 1877, when a caterpillar was observed to be causing severe damage to the foliage of coconuts on the main island of Viti Levu. The larva feeds on the underside of the leaflets of the coconut palm, the green tissue being removed from between adjacent veins, causing characteristic longitudinal scars, During severe outbreaks, palms might be almost completely defoliated, so that the nuts failed to mature, a constriction occurred in the trunk, and death of the tree might result.

Severe outbreaks occurred from time to time on Viti Levu, but as coconuts were not grown commercially on this island, the economic loss was not great. However, when the pest began to spread, about 1918, to the islands east of Viti Levu, there was great consternation. Rigid quarantine measures were adopted, to prevent its further spread, and considerable numbers of coconuts were felled near the port of Levuka. In 1924 the Levuana Committee, referred to above, was formed, financed by a tax of 2s. 6d. per ton on copra, and an equal contribution from the Fiji Government.

In June, 1923, Mr. H. W. Simmonds, the Government Entomologist, was sent on an eight months' tour of the New Hebrides, Bismarck Archipelago, Solomon Islands and New Guinea. The purpose of the tour was to seek the native habitat of *Levuana*, which

had no known parasites in Fiji, and appeared to be an introduced insect. Simmonds failed to find the insect, nor has it yet been observed outside Fiji.

The Levuana Committee then sent Mr. A. M. Lea and an assistant to Java and Malaya, to attempt the introduction of parasites known to occur on the allied Zygænid, *Artona catoxentha* Hamps. Two shipments of parasites were made from Java, but failed to survive the journey.

Dr. Tothill and Messrs Taylor and Paine arrived in Fiji in 1925, and Taylor was sent on a tour of New Guinea and New Britain, to continue the search for the native home of *Levuana iridescens*. He did not find the insect, but observed four species of allied Zygænids, whose larvæ fed in a manner similar to that of *Levuana*. Several species of parasites occurred, but hosts and parasites were both so rare that no attempt was made to introduce the latter to Fiji.

Meanwhile, Simmonds had been sent to Malaya to await an outbreak of *Artona catoxantha*, when it was hoped that sufficient parasitized larvæ could be obtained to provide strong colonies for shipment. It had been decided to attempt the introduction of the Tachinid *Ptychomyia remota* Ald. and the Braconid *Apanteles artonæ* Rohw., which appeared to be the main controlling agents in Malaya. As Artona was normally a rare insect, it was necessary to await one of its occasional localized outbreaks. Taylor arrived in Malaya on his way to Cochin China, continuing his search for the home of *Levuana*, and his arrival coincided with an outbreak of *Artona*. Consequently he remained in Malaya to assist Simmonds in the collection and shipment of parasitized material. The transporting of *Ptychomyia remota* to Fiji was successfully carried out, and the Clerid beetle *Callimerus arcufer*, Chapin. was also brought in. All the Apanteles died before the completion of the journey. The Tachinid, freed from hyperparasites which attacked it in Malaya, brought about complete suppression of its host in a very short time.

Apart from the fact that the *Levuana* campaign was extremely successful, there were associated with it some phenomena of peculiar interest. In the first place, there is the unsolved question of the native habitat of *Levuana iridescens*. As has been stated above, search in the Solomon Islands, New Guinea, New Britain and the New Hebrides failed to reveal its presence. Indo-China was considered a possibility, as ships in the sandalwood trade used to ply between there and Fiji during the last century, but no search was made there because of the success of Ptychomyia, and because later work indicated that the Solomon Islands or the New Hebrides were more likely habitats. It was in the Solomons that the species most closely allied to *Levuana* was found.

On the other hand, all the evidence indicated that *Levuana* was not a native of Fiji. Before the introductions from Malaya, there were no parasites of the moth in Fiji, though all the allied species of Zygænids found in the Solomon Islands and the New Guinea region were rare and heavily parasitized. Also, until about 1918, the moth was not found outside the island of Viti Levu. Finally, Taylor points out that *Levuana iridescens* is as specialized as the closely related Zygænid found in the Solomon Islands, and more specialized than *Artona*, which is a native of Asia. As the insect fauna of both Asia and the Solomons is very rich compared with that of Fiji, an insect native to Fiji would be expected to be less specialized than its relatives from Asia and the Solomon Islands. It was finally concluded that *Levuana iridescens* was probably introduced from the Solomons or New Hebrides, possibly in the form of pupæ on the leaves of the host plant.

An interesting study arising from the *Levuana* campaign was that made by Simmonds of the moth *Artona catoxantha* in Malaya.[23] Normally it is a rare insect, and very difficult to find, but occasionally, during a dry season, it occurs in epidemic form in very localized areas, perhaps only a few acres in extent. These few acres may be almost completely defoliated, while areas of palms in the immediate vicinity are undamaged. During these severe outbreaks, there is not the complete overlapping of generations which one commonly finds among insects in tropical countries. The

greatest difference in age between the stages of the life-history found by Simmonds at any given time was 20 days, and this condition continued through succeeding generations of *Artona*. Epidemics were normally brought to a close by the advent of the rainy season. Another phenomenon was that, though the duration of one generation of *Artona*, from egg to egg, is about 35 days, during outbreaks a period of about 45 days occurred between the mass appearances of any given stage of the insect.

This state of affairs was explained by Simmonds as being due to the activities of *Ptychomyia*, which was by far the most common parasite during outbreaks. Normally the Tachinid lays its eggs on fourth-instar larvæ, and its life-history from egg to egg occupies 19 to 20 days. When a brood of caterpillars from an individual lot of *Artona* eggs is attacked by *Ptychomyia*, the adult flies emerge at about the same time as the moths which are produced from unparasitized caterpillars. Where all stages of *Artona* are present, the parasites would oviposit on fourth-instar larvæ from an earlier batch of eggs. However, under epidemic conditions, the flies multiply rapidly, and the stage is reached where practically all fourth-instar larvæ are killed. This creates a break in the overlapping of generations, and causes an extension of the time between mass incidence of any given stage of the host in the field. Consequently, when a batch of adult parasites emerges, there are no suitable hosts available, and the fly has to wait for them, when it deposits its eggs eagerly, and considerable superparasitism occurs. This does not greatly affect the reproduction of the parasite, as one healthy individual emerges from a host which has been superparasitized. The parasites are so numerous and so eager to lay that all fourth-instar larvæ are again killed, and so the break in generations is perpetuated.

Simmonds states that the same phenomenon was observed with *Levuana iridescens* in Fiji in three localities only. These were all isolated groups of coconuts, two of them small islands. There seems little doubt that the break in generations is due to localization of the host in a small area. Where larger areas are involved, the adult parasites, which have strong powers of flight, would be able to go far afield to find hosts at a suitable stage of development. In the case of *Artona catoxantha*, Corbett[1] advances a hypothesis to explain the localized nature of the outbreaks. His opinion is that the moth's normal habitat is the jungle, and that occasional flights of moths are carried by wind to restricted areas of coconuts, causing heavy infestation in a small area.

(B) *Aspidiotus destructor.*

We shall consider now the campaign against the scale insect, *Aspidiotus destructor*, Sign., a full account of which has been given by Taylor in the Bulletin of Entomological Research.[31] The following remarks have been extracted from this publication. The scale, which is widely distributed throughout the tropics, attacks a great variety of host-plants, and can be very injurious to coconut palms and bananas. In Fiji it was first reported as a pest of bananas, and later became a serious pest of coconuts. By 1920, its spread among coconut plantations had caused alarm, so that quarantine measures were instituted to prevent its further dissemination among the islands of the Fiji Group. As was mentioned earlier, H. W. Simmonds was sent to Tahiti to introduce parasites. However, during the next few years the pest continued to increase in numbers and distribution, and by 1927 was the most serious pest of the coconut palm in Fiji. During epidemic outbreaks, the whole of the lower surface of the coconut leaflets might be covered by a yellow crust of scales, and defoliation and even death of palms frequently resulted.

In 1926, Taylor investigated the parasites and predators of *Aspidiotus destructor* and the allied *Hemiberlesia palmæ* in Java, and early in 1927 colonies of various species of parasites and predators were shipped to Fiji (see Appendix). However, they did not exercise any significent controlling effect, though the Coccinellid *Scymnus* sp. became established in the field. In 1928, Taylor proceeded to Trinidad, to investigate various species of Coccinellids which were known to

attack *Aspidiotus destructor*. As a result, five species of Coccinellids were shipped to Fiji, arriving there in March, 1928.

It was soon evident that *Cryptognatha nodiceps* Mshl. was by far the most efficient of the predators, so that after the first six months, breeding of the others was discontinued. *Cryptognatha* was liberated on all the islands where *Aspidiotus* occurred, in colonies of 100 to 500, and its controlling effect was remarkable. Taylor states that within nine months of the arrival of the shipment in Fiji, the scale had been brought under control in the more important islands, and after 18 months *Aspidictus* was, in many areas, very difficult to find.

Taylor lists the attributes of *Cryptognatha* which explain its great efficiency. Among these are its great voracity, its concentration on *Aspidiotus destructor* as a host, its long adult life, high reproductive capacity, and great powers of dispersal. He then makes some interesting comments on the relative efficiency of parasites and predators as controlling agents for *Aspidiotus destructor*. In Fiji, this scale occurred in irregular outbreaks of great severity, with which local parasites and predators were unable to cope. When the leaves of a palm reached the stage of being completely covered by scales, emerging larvæ wandered over the leaves in countless thousands, seeking a place to settle down. Great numbers perished, but many managed to be conveyed to neighbouring palms on the bodies of passing birds and bats. In this way the infestation could spread rapidly, and to prevent this spread a parasite or predator had to be capable of suppressing the pest before the leaves became completely covered with scales. Taylor considers that only a predator like *Cryptognatha*, of great voracity and a reproductive potential comparable to that of its host, could fulfil the requirements. A parasite with a reproductive rate similar to that of the host could not catch up with an outbreak, as each parasite destroys only one host individual, compared with the hundreds devoured by an efficient predator.

Taylor's conclusion is that, to control a scale insect which occurs in irregular and severe outbreaks, one should seek predators, and that the qualities necessary for success in the predator are great voracity and an egg-production and length of life-cycle comparable to that of its host.

(C) *Tirathaba trichogramma*, Meyr.

In 1929 Taylor investigated the problem of early nutfall from coconut palms in Fiji, and published his results in the form of a Bulletin issued by the Department of Agriculture.[29] He concluded that the main cause of nutfall was the work of the Pyralid moth, *Tirathaba trichogramma*, Meyr., and that copra production could be increased by over 30 per cent if this insect were eliminated. He stated that certain favourably situated female flowers on each spike were destined to remain on the spike and reach maturity, whereas other flowers and young nuts were destined to fall early. Whenever attack by *Tirathaba* larvæ—which bore into male and female flowers—caused the fall of female flowers which had been destined to reach maturity, a reduction in yield was caused.

Corbett, in Malaya, as the result of lengthy investigation of the allied moth, *Tirathaba rufivena* Walk., had concluded that it had no effect on premature nutfall, and Paine[15] expressed doubt as to whether *T. trichogramma* caused any significant reduction in yield in Fiji. However, as a result of Taylor's findings, it was decided to attempt the control of *Tirathaba* by introducing parasites of the allied *T. rufivena* and *T. mundella* from Java. Hence, in 1929, Paine proceeded to Java, where he carried out investigations covering a period of 18 months on the pest species and their parasites. Apart from the data presented in a Bulletin of the Fiji Department of Agriculture,[15] the account of the excellent work done by Paine during this period exists only in manuscript. The following account is taken from the above-mentioned Bulletin.

Paine found numerous parasites of *Tirathaba* in Java, of which three species were inportant and widely distributed. These were the Scelionid, *Telenomus tirathabæ*, Ferr., an egg-parasite, the Braconid, *Apanteles tirathabæ*, Wilk., and the Tachinid *Erycia basifulva*, Bezzi, the two latter being parasites of the larva. *Apanteles* appeared to be the most promising, as it was the most effective parasite in Java, despite its being

attacked by hyperparasites. In February, 1930, Taylor took colonies of *Apanteles* to Fiji, and the parasite, freed from its secondary parasites, rapidly became established in the vicinity of Suva, and attacked a higher percentage of *Tirathaba* larvæ than it had done in Java.

After further study in Java, Paine found that *Erycia basifulva* did not compete with *Apanteles*, as it attacked more mature larvæ, and early in 1931 he brought colonies of the Tachinid and of *Telenomus* to Suva. *Telenomus* was later recovered in the field, but in June the breeding stock of *Erycia* had died out, after two large colonies had been liberated. By the end of 1932, the introduced parasites showed little evidence of bringing their host under control, so it was decided to reintroduce *Erycia basifulva* and to import an Ichneumonid parasite of the larva, *Nemeritis palmaris*, Wilk., which occurred in small numbers in Java, and was an important parasite of *Tirathaba rufivena* in Malaya. Consequently Paine again visited Java, and in May, 1933, arrived in Fiji with colonies of *Nemeritis*, *Erycia*, and another species of Tachinid, *Sturmia painei*, Baran. The *Sturmia* colony died out, after only a few adults had been liberated at Lautoka, but breeding and distribution of *Nemeritis* and *Erycia* proceeded satisfactorily, and both became established in the field.

As mentioned above, much of Paine's work on *Tirathaba* and its parasites has not been published, but he has given me permission to make use of his manuscript, from which the following notes on the bionomics of *Erycia* and the ingenious technique employed in breeding it have been abstracted.

The fly is apparently a coconut-frequenting species, as it attacks only those species of *Tirathaba* which feed on coconut palms. It is a strong flier, and will not mate readily in captivity. Oviposition commences nine or ten days days after mating, and during this period the eggs descend from the ovaries into the uterus, which becomes greatly distended with four or five thousand microtype eggs. The female fly now seeks coconut flowers where larvæ of *Tirathaba* are feeding, and among these flowers she scatters her eggs, which adhere to the surface on which they fall.

The eggs do not hatch until swallowed by a host caterpillar, and meanwhile can retain their vitality, under humid conditions, for up to 13 days. When the maggot is fully fed, it pupates within the cocoon of the host. The adult fly emerges from the puparium during the morning, usually between 9 a.m. and 1 p.m. The flies are stimulated by sunshine, and mating in cages is rarely attempted on sunless days. When kept in glass jars, and fed regularly with honey-water, they lived as long as three weeks, but in cages their life was shorter, partly owing to damage sustained by striking the walls of the cage, and partly because they failed to find the water provided for them in the cages.

The main difficulties associated with breeding the parasites were their unwillingness to mate in a confined space, and the necessity to keep the females alive for at least eight days after mating, so that their eggs might descend into the uterus and mature. Moreover, though mated females would oviposit readily in glass jars or tubes, only a small percentage of the eggs were eaten by caterpillars. To cope with these difficulties, Paine evolved the following breeding technique:—

For mating purposes, the smallest suitable cage was about six feet high, six feet long and three feet six inches wide. The basal portion was of wood, and the roof and upper portions of the walls were of wire gauze. Better illumination, without an undue rise in temperature, could be obtained by using calico shades outside the cage, with a wide air-space between gauze and calico. Food consisted of sponges soaked in diluted honey and water, and suspended from the roof, and pieces of loaf sugar. Male coconut flowers, and numerous *Tirathaba* larvæ were placed on a wooden shelf, built about three feet from the floor, at the end of the cage opposite the door, and where possible, fresh flowers were added daily. The flowers and larvæ seemed to provide an additional stimulus for the flies to mate, and to accelerate the passage of eggs from the overies to the uterus. During sunny days, the flowers were sprayed with water at least three times per day, and in all weather it was necessary to see that the flowers were

well moistened when the cage was first visited in the morning. A shelter was placed over the cage to keep off heavy rain.

From 50 to 100 flies could be placed in a cage of the size described, but the percentage of matings of female flies never reached 50. However, at least 10 per cent of female flies usually mated and lived long enough for the eggs to mature, thus providing an ample supply of viable eggs. The females were left in the cage for five or six days, after which they were removed to a glass jar and fed with honey-water. Here they were kept until they died, after which they were dissected, and the uterus removed from each individual. If some of the eggs in a uterus were not mature, they would continue to develop if the unbroken uterus, freed from all adhering tissues, were kept in a moist atmosphere. This was accomplished by placing the uterus on the underside of the lid of a small glass pot, in which was kept a small plug of cotton wool, well soaked in water. Embryos were known to be mature when the black mouth-parts could be seen within the egg.

The next step was to place mature eggs in water on a glass slide, forming a "smear," and, using a low-power binocular microscope, transfer them with a fine brush to male coconut flowers. A thin slice was cut from the base of each flower with a sharp, stainless-steel knife, thus leaving a flat, moist surface, to which the eggs adhered when the brush, carrying the eggs, was drawn across the surface. Two flowers, carrying eggs, were placed in a glass tube, with a single *Tirathaba* larva, early fifth-instar larvæ being preferable, and fourth—or even third—instar larvæ giving better results than late fifth-instar. Larvæ about to moult were not used. The tubes were then stacked, stoppered-end up, and left overnight. By the following day, most of the larvæ had eaten through the base of the flowers, and swallowed some of the eggs. When two eggs were placed on each flower, as high as 65 per cent of parasitism resulted, but when mature eggs were abundant, from six to ten were placed on each flower, and over 90 per cent of the larvæ were parasitized. After swallowing the eggs, the larvæ were fed with male flowers until they pupated.

(D) *Promecotheca reichei*, Baly.

The campaign which led to biological control of this insect is described by Taylor in an excellent publication of the Commonwealth Institute of Entomology,[32] from which the following notes have been abstracted:—

P. reichei feeds on the coconut palm, the larvæ mining within the leaflets, and the adults feeding on the leaf tissue. Though present throughout Fiji, it caused severe damage mainly in the comparatively dry Lau group of islands, intermittent outbreaks of great severity causing a great reduction, or even cessation, of nut-production by the palms. Local parasites of the egg and larva were capable of controlling their host under the normal condition of completely overlapping generations. Where overlapping was greatly restricted, they were unable to prevent outbreaks, and hence Taylor sought in Java a parasite which would be capable of suppressing the pest under such conditions. His quest was successful, and in 1933 he introduced the Eulophid *Pleurotropis parvulus*, Ferr., which was one of a number of parasites of *Promecotheca nuciferæ*, Maulik, discovered by Paine while he was studying *Tirathaba* spp. *P. parvulus* proved to be another remarkably successfully introduction, bringing about complete control of its host in individual areas within a few months of liberation.

The study of the work of controlling *P. reichei* is of particular interest for two reasons, first the break in overlapping of generations, and second the necessity to find a parasite with specific qualities required under local conditions.

Taylor points out that multiple-stage outbreaks of the pest, that is, with completely overlapping generations, occurred at times, due to fluctuations in the balance between the pest and local parasites, to introductions of the pest, without its parasites, to new localities, and to destruction of the parasites by hurricanes. Usually such outbreaks were very localized, and of small consequence, except in the case of those caused by hurricanes, which could be quite extensive and severe. One-stage outbreaks were caused by the intervention of

the mite *Pediculoides ventricosus*, Newp. in a multiple-stage outbreak. This came about as follows: The conditions required by the mite are that the *P. reichei* individuals should be crowded together, and the weather dry, as heavy rains drastically reduce the mite population. Crowding of *P. reichei* occurs even in a multiple-stage outbreak confined to a few palms, because the beetle is gregarious, and does not spread until forced to do so by lack of food. When the mite finds a crowded colony of *Promecotheca* at the beginning of the dry season, conditions for its multiplication are ideal. It enters the larval mine through the slit made by the newly-hatched larva, and attacks larvæ, pupæ, and newly-emerged adults, penetrating the integument of its victim with its mouth-parts, and sucking out the body fluids. In a very short time all stages of the host except eggs and adults are destroyed, so that food for the mites becomes very scarce, though they can feed for about two weeks on the remains of their dead hosts. The longevity of the adult beetle is about a month, during the last fortnight of which the female lays its eggs. (Other approximate life-history figures are: Incubation—19 days; Larval period—50 days; Pupal period, including pre-emergence resting period of adult—20 days). Consequently, the stage is reached when the numbers of the mite have been drastically reduced, and the difference in age between the oldest and youngest surviving larvæ of *P. reichei* is about two weeks. These larvæ are then the only stage of the beetle in the field.

Towards the end of the larval stage, and during the pupal stage, the population of mites again begins to increase, but not sufficiently to have much effect on the next generation of beetles, so that there is a very great increase in population of the latter. At the end of this second generation, the mite is again very numerous, and parasitism of the later pupæ reaches practically 100 per cent. Hence the period during which beetles emerge from the mines is restricted to about ten days. The two generations of the beetle have occupied about six months, and the wet season now sets in. The mites again die off in great numbers, as only eggs and adults of the host are present, and they are unable to build up during the wet season. A very numerous brood of beetles emerges during the middle of the wet season, the emergence period covering about a month, and vast numbers of eggs are laid over a period of about 5½ weeks. The local egg-parasite, *Oligosita utilis*, Kow., now steps in, and by parasitizing 100 per cent of the earlier batches of eggs, reduces overlapping to about three weeks. By the time that the fourth generation of beetles is emerging, the dry season has again set in, and the mite takes over once more. Hence we have the phenomenon of parasites—primarily the mite and secondarily the egg-parasite—producing conditions which make control of a pest by local parasites impossible.

As a result of his study of the cause of one-stage outbreaks, and the reasons for the ineffectiveness of local parasites, Taylor listed seven desirable attributes for a parasite which would be able to control *P. reichei* under the existing conditions. They were as follows:—

(1) It must attack larvæ of all ages, and also pupæ. This would probably allow time for three generations of the parasite during one of the host, and would reduce the period when no hosts were available to about three weeks. The local larval parasite, *Elasmus hispidarum*, Ferr., did not attack pupæ and consequently had to survive a period of about six weeks without hosts.

(2) It must be an internal parasite. It would then probably avoid attack by the secondary parasite, *Tetrastichus taylori*, Ferr., which reduced the value of the external parasite, *E. hispidarum*. Also it would be less exposed to attack by the mite.

(3) Its adult life must be at least three weeks, to tide it over the period when hosts were not available.

(4) One generation must not cover more than one month, thus allowing three generations of the parasite to one of the host.

(5) Its biotic potential must be not less than 20.

(6) It must be very active, and capable of rapid spreading.

(7) It must not be adversely affected by the climatic conditions of Fiji.

Of the parasites available in Java, *Pleurotropis parvulus* most closely fitted these requirements, and hence was selected by Taylor, even though it was comparatively rare. *Dimmockia javanica*, Ferr., the most successful parasite under Javanese conditions, and *Pleurotropis painei*, Ferr., a pupal parasite, were also brought to Fiji, but as had been expected, proved useless under the conditions of a one-stage outbreak. The success of *P. parvulus*, however, proved a fitting sequel to a very pretty example of entomological detective work.

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APPENDIX.

LIST OF BENEFICIAL INSECTS INTRODUCED INTO THE FIJI ISLANDS.

Year	Beneficial Species	Host Species	Introduced From	Remarks
1911	Agromyza, lantanae, Frogg.	Lantana camara L. ..	Hawaii ..	Well established.
1912				
1913	Microceromasia sphenophori, Vill. ..	Rhabdoscelus obclscurus Boisd.	Hawaii ..	Established.
1917				
1913	Plæsius javanus, Er.	Cosmopolites sordidus, Germ.	Java	Established. Exercises considerable control of host.
1918				
1917	Scolia manilæ, Ashm.	Rhopaca vestita, Arrow. Rhopaca subnitida, Arrow. Adoretus versutus, Har.	Hawaii ..	Established.
1920				
1921	Aphytis chrysomphali, Mercet. ..	Aspidioctus destructor, Sign.	Tahiti .. Java	Established.
1927				
1920				
1921	Aspidiotiphagus citrinus, Craw. ..	,,	Tahiti ..	Established.
1922				
1923	Thecla echion L.	Lantana camara L. ..	Hawaii ..	
1923	Thecla bazochii, God.	,, ..	Hawaii ..	Established.
1924	Orcus australasiæ, Boisd.	Diaspine scales	Australia ..	
1924	Orcus chalybdeus, Boisd.	,, ...	,,	
1924	Leis conformis, Boisd.	Aphids	,,	
1924	Cryptolæmus montrouzieri, Muls. ..	Mealybugs	,,	Established.
1924	Chrysopa ramburi, Schreider	Various	,,	Established.
1925	Ptychomyia remota, Ald.	Levuana iridescens B-B.	Malaya ..	Completely controls host.
1925	Callimerus arcufer, Chap.	,,	,,	
1925	Trichogramma pretiosa, Ril.	Various	Hawaii ..	
1925	Chalcis obscurata, Walk.	,, ...	,,	
1925	Ecthromorpha maculipennis	,, ...	,,	
1925	Frontina archippivora, Will.	,, ...	,,	
1925	Casinaria infesta, Cress.	,, ...	,,	
1925	Chelonus blackburni, Cam.	,, ...	,,	
1925	Euplectrus platyhypenæ, How. ..	,, ...	,,	Established.
1925				
1928	Microbracon omiodivorum, Terry. ..	,, ...	,,	
1927	Trichogrammatoidea nana, Zehnt. ..	,, ...	Java	Established. Already in Fiji.
1927	Chalcid sp.	Levuana iridescens B-B.	,,	
1927	Scymnus sp.	Aspidiotus destructor, Sign	,,	Established.
1927	Spaniopterus crucifer, Gahan. ..	,,	,,	
1927	Comperiella unifasciata, Ishii.	,,	,,	
1927	Casca parvipennis, Gahan	,,	,,	
1927	Aleurodothrips fasciapennis, Frankl. ..	,,	,,	
1928	Cryptognatha nodiceps, Mshl. ..	,,	Trinidad ..	Completely controls host.
1928	Cryptognatha simillima, Bic.	,,	,,	Established.
1928	Azya trinitatis, Mshl.	,,	,,	
1928	Scymnus aeneipennis, Sic.	,,	,,	
1928	Azya luteipes, Muls.	*Coccus* spp.	Hawaii ..	
1928	Teleonemia scrupulosa, Stal.	Lantana camara, L. ..	,,	Established.
1928	Spalangia cameroni, Perk.	Housefly	,,	
1929	Copris incertus, var. prociduus, Say. ..	Dung-burying Beetle ..	Hawaii ..	Established.
1930	Liothrips urichi, Karny.	Clidemia hirta, D. Don. ..	Trinidad ..	Excellent control.
1930	Apanteles tirathabæ, Wilk.	Tirathaba trichogramma, Meyr.	Java	Established.

LIST OF BENEFICIAL INSECTS INTRODUCED INTO THE FIJI ISLANDS (*continued*).

Year	Beneficial Species	Host Species	Introduced from	Remarks
1931 1933	Erycia basifulva, Bezzi.	Tirathaba trichogramma Meyr.	Java	Established.
1933	Telenomus tirathabæ, Ferr.	,,	,,	Established.
1931	Megarhinus splendens, Wied.	Mosquitoes	,,	Established.
1931	Mesembrina meridiana, L.	Housefly	England	
1933	Pleurotropis parvulus, Ferr.	Promecotheca reichei, Baly.	Java	Established. Completely controls host.
1933	Cremastus sp.	Nacoleia octasema, Meyr.	,,	
1933	Megarhinus inornatus, Walk.	Mosquitoes	New Britain	
1933	Nemeritis palmaris, Wilk.	Tirathaba trichogramma Meyr.	Java	Established.
1933	Sturmia painei, Baran.	,,	,,	Only a few adults liberated.
1935	Tetrastichus giffardianus, Silv.	Fruit flies	Hawaii	Established.
1935	Opius humilis, Silv.	,,	,,	*
1935	Cremastus flavoorbitalis, Cam.	Pyralidæ	,,	
1936	Anagyrus saccharicola, Timb.	Trionymus sacchari, Ckll.	Hawaii	
1936	Bactra truculenta, Meyr.	Cyperus rotundus, L.	,,	
1936	Athesapeuta cyperi, Marsh.	,,	,,	
1937	Dirhinus giffardii, Silv.	Fruit flies	India	
1938	Melittobia indicum, Silv.	,,	Australia	
1938	Pachylister chinensis, Quens.	Housefly	Java	Established.
1941	Microphanurus basalis, Woll.	Nezara viridula, L.	Australia	Established.
1943	Diadromus collaris, Grav.	Plutella maculipennis, Curt.	New Zealand.	

Since this paper was read, in February 1949, the following species have been introduced:—

1949	Trichopoda pennipes, F.	Pentatonid and Coreid Bugs.	Florida, U.S.A.	
1950	Apanteles marginiventris, Cress.	Cirphis unipuncta and other noctuids.	Hawaii	
1950	Eucelatoria armigera, Coq.	,,	,,	

* Since the preparation of this paper, *C. flavoorbitalis* has been found to be well established as a parasite of *Marasmia venilialis*, the Rice leafroller, on which it appears to exert a considerable measure of control.

CONTROL OF THE BANANA SCAB MOTH, NACOLEIA OCTASEMA MEYR.

In an article in a previous issue of this *Journal*[1] spraying experiments for control of the Banana Scab Moth were described. Experiments have now been concluded, and the following measures can be recommended for production of bunches completely free from scab:—

(1) When the closed bunch has emerged to about half the height which it will reach in the erect position, spray the bunch and the youngest four or five leaves from above with a spray fluid consisting of one part of DDT 20 per cent Emulsion in 100 parts of water (by volume).

(2) When the bunch has turned over to the horizontol position, carefully remove all the bracts, and treat the hands with two per cent DDT dust, using a puff-duster.

This method has been used for several months on the Principal Agricultural Station at Koronivia, and has been very successful under all weather conditions. It is important to spray before the bracts at the tip of the bunch have begun to uncurl. Spraying alone gave complete control in about 30 per cent of bunches so treated, but the remaining bunches showed scab on the distal hands. This indicates that some larvæ hatch after the bracts have begun to fall off, and can enter the bunch without receiving a lethal dose of DDT. Hence both spraying and dusting are necessary.

The spray was applied with a knapsack sprayer and extension pipes, using about one pint of fluid per plant, but a smaller type of sprayer, suitable for small growers, was tried with satisfactory results. It is a small pneumatic sprayer, with trigger release, which can be held aloft on a long pole. A pilot model was obtained from Australia at a cost of 25s. This type of machine would be useful also for spraying gardens.

—B.A.O'C.

LITERATURE CITED.

(1) O'Connor, B. A., "The Banana Scab Moth, *Nacoleia octacema* Meyr., and its Control"—*Fiji Agric. Jour.* Vol. 20, No. 3, 1949.

DAIRY RESEARCH AND HORMONES

Extract from Overseas Press Services, Central Office of Information, London.

Every dairy farmer is familiar with the fact that the quality of the milk from his beasts improves as soon as they go out to grass in the spring, but it is only recently that the scientist has sought the underlying reasons for this improvement. They are however very well worth careful study in view of the great value of milk as a well balanced food.

Nine-tenths of milk is indeed water. But great food value lies in the odd tenth, consisting of protein, fat (which forms the cream) and sugar. During the winter months milk becomes even more watery than usual, although the amount of fat in it generally stays much the same. The explanation might seem obvious; monotonous and often poor food appearing as the main factor. But experiments carried out in Britain very largely at the National Institute for Research in Dairying at Shinfield, Reading, soon showed that as often happens, the apparent explanation was not the right one. Even when cattle were given special rations during winter months they still gave typical winter milk. As soon as they went out to grass in the spring, however, the quality of the milk improved in the usual way.

What was the vital substance in the young grass? Britain's scientists found their first clue to its nature in some work done for quite other purposes in Australia. Sheep breeders in Western Australia had been experiencing great difficulties especially with their valuable Merino sheep. Mortality among ewes and lambs became so high that experts were called in. Eventually it was discovered that the trouble was commonest in areas where a special kind of clover had been planted. This particular variety, called subterranean clover, had been introduced because it flourished where other kinds were unsuccessful. With its help huge areas of semi-desert had been turned into fertile pastures. On closer investigation the scientists discovered that the sheep deaths were caused by an excess of a substance contained in the clover and closely resembling an oestrogen hormone. Hormones are "chemical messengers" (produced in the bodies of animals and men) which even in minute quantities regulate vital functions such as the sexual cycle. Those which affect sex functions in females are known as oestrogens. This chemical balance is always very delicate and the taking of excessive amounts of extra substances like oestrogens in food can throw it out of gear. Small doses may however stimulate milk production.

Guided by the clue from Australia, workers in Britain decided to find out whether spring grass contained any substance akin to oestrogens. Samples of grass and clover were cut from pastures at different times of the year. A careful chemical extraction process was carried out and resulting product tested for oestrogen activity on mice. Results were conclusive. Clover and some of the grasses showed oestrogen-like qualities; these were completely lacking in hay, the staple winter-time cattle food.

These results tied up neatly with experiments made by other British research workers who had been experimenting with synthetic "oestrogens" like stilboestrol. They had discovered in 1940 that, contrary to general belief at the time, oestrogens stimulated milk production in animals instead of retarding it. This led to some experiments with goats, in which a big increase in milk yield was obtained with the aid of a few small tablets of synthetic oestrogen. The economic importance of this was immediately recognised for the experiments pointed the way not only to increasing the supply from existing herds but also to obtaining milk from animals which would otherwise be barren and valueless. For example with the help of "oestrogens" farmers were able to obtain three gallons or more of milk daily from animals months before they would normally have given any at all.

This new British discovery of oestrogen-like substances in growing grass is therefore likely to be of the utmost importance to dairy farmers all over the world. Several practical possibilities are immediately apparent. Thus it may be possible substantially to increase milk supplies by supplementing normal winter diet with artificial

oestrogens, of which several different kinds are now available through ordinary commercial channels. Alternatively, research may show how natural oestrogens can be preserved when grass is dried either by conventional haymaking or in various methods of artificial drying which are now being increasingly widely used especially in Britain.

Equally important will be the investigation of the role these substances play in the internal economy of plants. So far as existing knowledge goes, they are of importance only in the animal reproductive cycle and there is nothing to indicate that they can play any important role in the life of plants. This line of research may also answer the very important—and hitherto unanswered—question of the origin of vitally important oestrogens in animals. Are they perhaps derived from plants, either directly when they are eaten as food, or indirectly through the flesh of the animals which feed on the plants.

These and many other questions remain to be answered, but there can be no doubt that this new field of research developed in British laboratories opens up possibilities of immense importance not only in practical dairy farming but also in fundamental research in biology and medicine.

SCHOOL FARM CLUBS

The project of Farm Clubs in schools is being rapidly developed by the officers of the Education Department and this work is now being organised by Mr. R. Hartley, Agricultural Education Officer, who arrived in the Colony in October of last year. During December a very successful show was held at Navua when a comprehensive range of exhibits was brought together for such a purpose: the show was opened by the Agricultural Education Officer and the exhibits included animals, poultry, fruit, sugar-cane, root crops, vegetables, dairy produce, cookery, mats and needlework. The judges included Messrs. Mune, S. Seru and Subramani of the Agricultural Department, Asaeli Rabuvocago and A. M. P. Jhinku, Father Waqa and Mesdames Little and Bradnam.

Similar shows have been organised in all parts of the Colony and the scope and quality of the exhibits have demonstrated that these Clubs have succeeded in attracting the interest and enthusiasm of the pupils.

THE TOXICITY OF CANDLENUT MEAL

As a candlenut oil extraction industry had been successfully started in the country it was considered desirable to see if the meal, which is a by-product of the extraction process, could be used as an animal feed.

It was decided to attempt to feed the meal to pigs, and three feeding trials have been conducted at Sigatoka using Large White and Tamworth weaners and porkers.

The meal was fed at various levels, the highest being in a ration in which it constituted 10 per cent of the feed. When the meal was included in the ration in small quantities the pigs found their feed unpalatable, their appetite was depressed, and growth was slowed down. When the meal was fed in the ration at the 10 per cent level, the animals ceased eating, lost condition, and stopped growing. The meal did not appear to be actually toxic at any level up to 10 per cent. However it appeared to induce a photo-sensitisation in the Large White pigs which grew worse as the level of the meal in the ration was raised. This condition caused acute sun-scald. It was not investigated further.

Thus we must reluctantly conclude that although candlenut meal may not be actually toxic if it constitutes up to 10 per cent of the ration, it does depress appetite and growth and is not a suitable pig feed. This conclusion is supported by evidence from pig feeders in Australia (Bostock, 1948). W.J.A.P. and W.I.L.

REFERENCE.

Bostock, F. Q., (1948)—*Queensland Agric. J.*, 67, 290.

FIELD SPRAYING

Since the introduction of practical selective herbicides in the United States approximately ten years ago there has been a tremendous development in the spraying equipment field. As a result of early trials a few farmers decided that they should have sprayers for their own use. Commercial sprayers then on the market had been developed for the application of insecticides and fungicides and were strictly specialised pieces of equipment with many features which did not appear essential to the application of weed killers. The result was that a few farmers set out to build their own equipment which naturally varied considerably in tank capacity, type of pump and design of boom. Reluctance to leave good wheat land idle for a year in order to control broad leaved annual weeds by summer following made farmers quick to appreciate that if these could be controlled with selective chemicals in the growing crops the productive acreage of their farms could be increased 10 to 20 per cent.

By 1947 manufacturers were producing weed spraying equipment in quantity, and while these machines varied greatly in construction they were all designed to apply solutions at from 75 to 100 gals per acre. At this time 2,4–D preparations were coming on the market, for use in solutions applied at from 80 to 160 gals per acre, but it was later suggested that this quantity of solution might not be necessary. Tests were carried out to determine if the chemical could be distributed as uniformly and effectively with low volumes of water as with high gallonages. Using a constant amount of chemical, the volume of solution ranged from 1½ to 180 gals. per acre. Suffice it to say that subsequent observations indicated entirely comparable results at both of the extremes and all intermediate rates.

Recommendations were therefore made that operators should obtain low-volume nozzles which would provide a rate of approximately 10 gals per acre. Reports later confirmed more satisfactory weed control than with the larger volumes of water. Field sprayers are now being distributed designed for the application of 2,4–D at the rate of 5 gals. per acre.

Sprayers are of three types, the tractor-mounted, the skid-mounted and the trailer unit. Generally farmers prefer the trailer type sprayer when the price can be kept at a reasonable figure. The tank must provide sufficient capacity to cover a considerable acreage without refilling, yet not too heavy when filled. A 100 gal. tank at the 5 gal. rate will permit spraying 20 acres without refilling. The booms should be of non-corrosive metal and from 24 to 40 feet in length, though a few operators on flat land with large fields are using booms up to 80 feet. The nozzle spacing naturally depends on the height at which the boom will be operated but a common spacing is 15 to 18 inches apart on the boom for small grain. All types of pumps are being used, and the use of proper strainers or screens is especially important with low volume nozzles. Proper calibration of sprayers is very important and it goes without saying that field sprayers must be built to withstand abuse. Operators who are content to plough at 3 m.p.h. apparently become so fascinated by the miracle of selective weed control that they will attempt to pull their sprayers 8 or 10 m.p.h. over the roughest land on the farm. Though remarkable progress has been made there is still need for improvement in farm sprayers. We have the chemicals to work with, and given improvement in design and greater durability there will be a sprayer on every farm in the grain growing area.—(Condensed from an article by W. P. Macdonald in *Agricultural Engineering*, Sept. 1948.)

PERSONAL NOTES

Readers will be interested to learn that, among the New Year Honours awarded in the Colony, two came to the Department of Agriculture:—

Mr. C. Harvey, Director of Agriculture, was awarded the C.B.E. in recognition of valuable services rendered over a period of ten years.

Mr. C. M. Dass, Agricultural Assistant, who has done extensive work on the breeding of cotton and rice varieties, was awarded the M.B.E.

A CENTRE OF BOTANICAL RESEARCH

Every year thousands of botanists, agriculturalists and horticulturalists from many countries make their way to the Royal Botanic Gardens at Kew, the garden-paradise on the banks of the River Thames six miles (ten kilometres) south-west of London.

"Kew," as it has been known for two centuries, is famous to laymen for its pleasant gardens and its beautiful flowers which have made it one of the sights of London. It is, however, also the home of a unique research organization, run by the Ministry of Agriculture and Fisheries and receiving an annual grant from the Government of £115,700.

One side of the Kew picture is that of the visitors, more than 1,750,000 of whom paid their penny entrance money in 1949, passed through the turnstiles, gazed at the luxurious array of flowers, admired the tall Pagoda that is the "trade mark" of Kew, and stared at the 214 feet (65 meters) high flagstaff presented by the Government of British Columbia and cut from a single Douglas fir.

The other side of the picture is one of constant careful work in the unique Herbarium, work the results of which are to-day seen in almost every country in the world. For Kew has played an important part in many a Commonwealth of Colonial development scheme of the last 100 years. The Natal tea industry, for example, was started from plants specially grown at Kew. Better bananas are now being produced in the West Indies on plants brought from Africa to Kew and reared there before being sent on westwards in special containers. Other countries have improved their tobacco production following advice from Kew, while during World War II certain methods of producing new kinds of rubber were first scientifically tested at Kew.

Cocoa Plant Research.

At present, cuttings and seeds of West Indian cocoa plants resistant to swollen-shoot disease are being reared at Kew and then sent to Africa, where it is hoped the new strains may benefit the cocoa industry. Little wonder, in fact, that Sir Edward Salisbury, the £2,000-a-year Director of Kew who recently visited Western Australia to advise the State Government there on setting up their own "Kew," once said: "We particularly welcome visitors who realise that the Gardens are not a public park but are a national centre for scientific research."

The students who take a two-year course at Kew—there are only a few dozen highly sought-after places—do, in fact, work in a unique botanical research station. The heart of the organization is the famous Herbarium, housed in a lovely red-brick building.

More than 4,000 botanists visited the Herbarium for research in 1949, and it is no unusual thing to see men from half-a-dozen countries at work in what looks, from the inside, like a well-windowed library with folders of plants taking the place of the books. There are between 5,000,000 and 6,000,000 dried specimens, as well as 45,000 living specimens in the Herbarium and to note all the specimens would occupy one person more than 40 years of continuous work.

Unexpected Sources.

New specimens come from the most unexpected sources. There was a Kew collector with the 18th century explorer Captain Cook, while last century Sir Joseph Hooker, one of the most famous Directors of Kew, brought back specimens from India, Tibet, Antarctica, Tasmania, and South Africa. During World War II, men of the Eighth Army sent back specimens from the Western Desert. Among other "non-botanical" contributors was the late Frank Smythe, a well-known British mountaineer.

After the war, the Netherlands was one of the many countries which added her quota, not only to the Herbarium, but to the plants in the garden, and when Dr. M. W. Rosen of the Dutch National Com-

mittee told the Director: "We want to thank you with flowers," Sir Edward chose 30,000 bulbs.

In 1949 alone, 18,879 new specimens were received, more than 4,500 were sent to botanists on loan—many of them to destinations overseas—while another 5,148 were distributed as duplicates.

All of this is additional to the work of Sir Edward himself, who receives up to 150 letters a day, and to that of the Curator of the Gardens, Mr. Wm. Campbell, who in a single year sends more than 8,000 packets of seeds to botanical gardens and horticultural institutions throughout the world.

UNUSUAL TASKS.

As examples of the unusual tasks which the Kew staff carries out, one member has recently returned from Africa where he accompanied a party from Britain's Medical Research Council looking for new sources of cortisons; another is now working in Southern Rhodesia in the anti-locust campaign. These men, as well as the rest of the Kew staff of 270, including 130 gardeners, 40 special police, and 50 scientists all come under Sir Edward's control.

So does the Jodrell Laboratory in which botanical detective work is carried out for Government and Commonwealth offices. Recently, for instance, a number of sacks which arrived in Britain from overseas were found to contain sand instead of their legal contents. Kew proved that the botanical fragments found in the sand could have come only from one particular territory. They had proved where the substitution had been made.

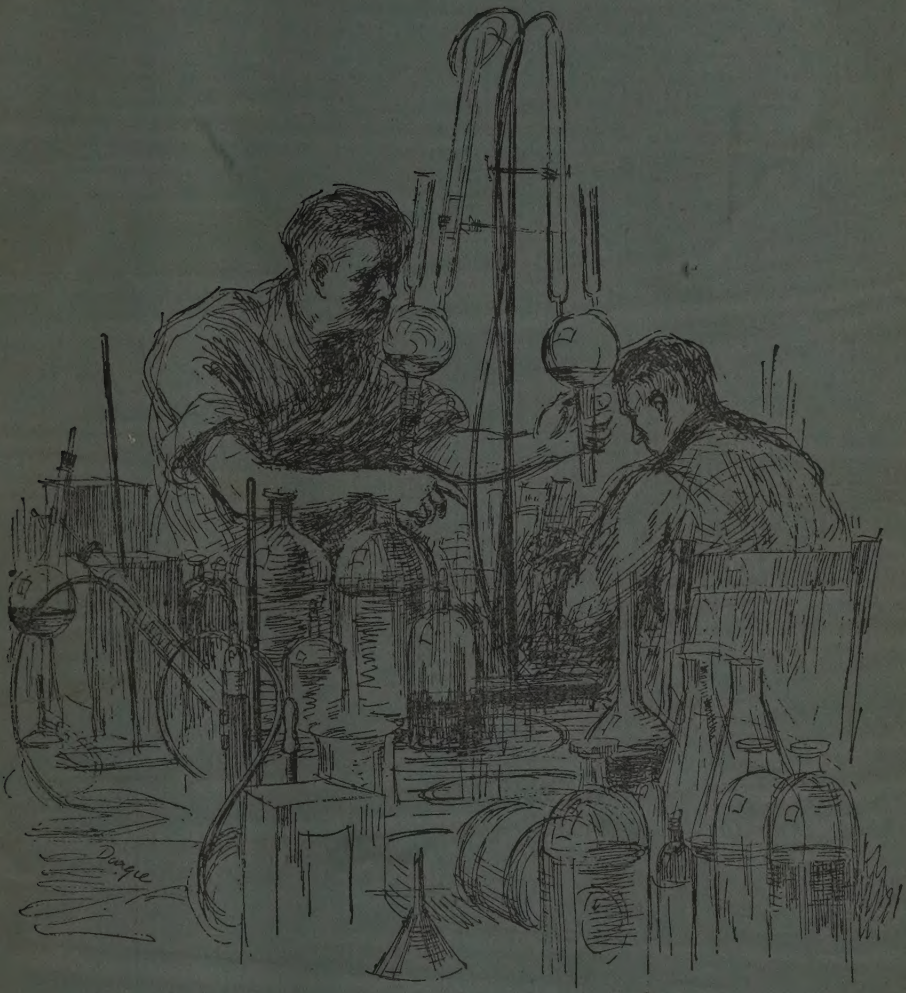
Yet in spite of the purely scientific aspect of the real work done at Kew—and there is nothing approaching the Kew record anywhere in the world—the Director has never lost sight of the less utilitarian aspects of botanical research.

"When I was teaching botany," he recently told me, "I pointed out to my students that there was one test they should apply to what they were learning. They should ask themselves 'Does it make any country walk more interesting? Does it make life more interesting?' If not, they might as well start studying something else."

One cannot help feeling that the seed of that enlightened idea is still somehow wrapped up with the packets that Sir Edward's staff sends all over the world.

—Extract from Overseas Newsletter (article by Ronald W. Clark).

HORIZONS WIDEN THROUGH SHELL RESEARCH . . .



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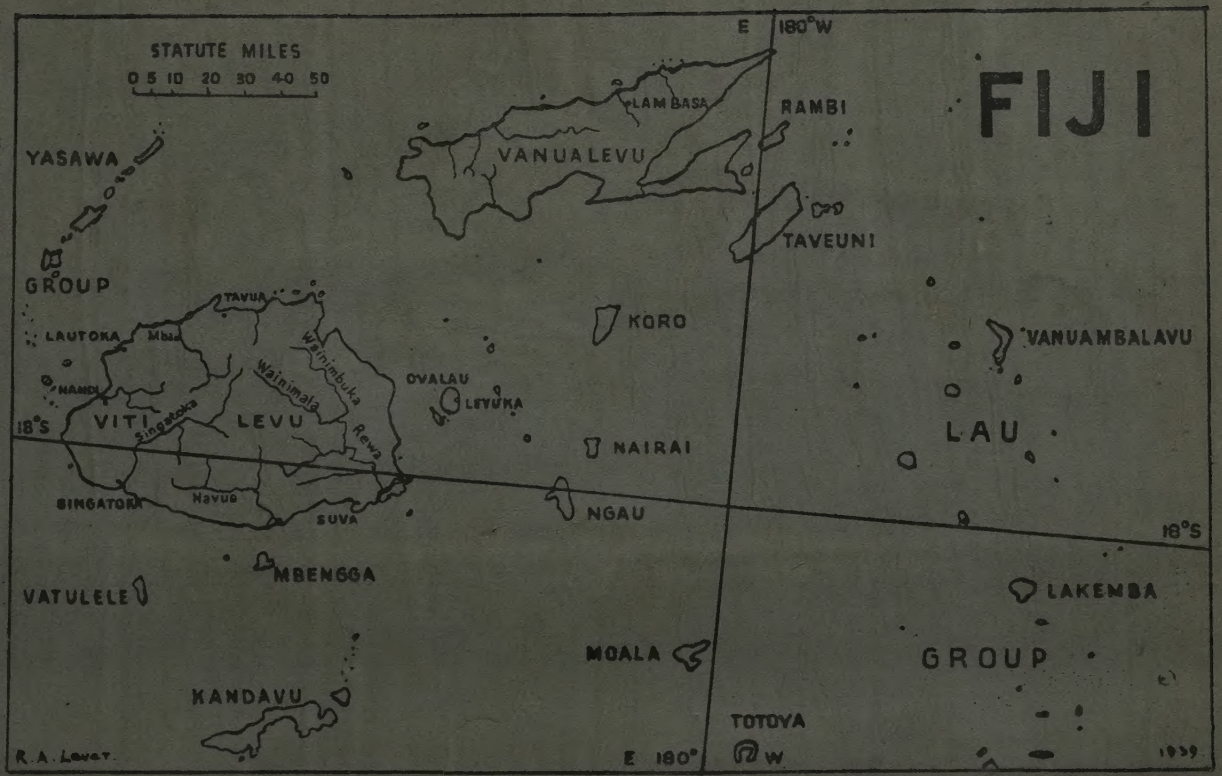

So as to include Kadavu and Totoya within the framework available the map has been rotated some 6° to the east.